

A281.9

A98A

reserve



United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 545

85

a

Energy and U.S. Agriculture: Irrigation Pumping, 1974-83

Gordon Sloggett



CURRENT SERIAL RECORDS

JAN 24 1986

USDA
NATIONAL LIBRARY

Energy and U.S. Agriculture: Irrigation Pumping, 1974-83. By Gordon Sloggett, Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 545.

Abstract

U.S. land irrigated with onfarm pumped water increased by 9.5 million acres to 44.5 million acres from 1974 to 1983. Higher energy prices increased energy pumping costs from \$551 million to \$2.5 billion. Pump irrigators applied energy-saving technologies such as low-pressure center pivots, which alone saved about \$72 million in 1983. Favorable economic conditions could lead to 3 to 4 million additional pump-irrigated acres in the water-short Great Plains by the year 2020 and significant increases in the more humid Eastern States. This report, the fourth in a series, updates the 1980 irrigation estimates and focuses on 1983 pump-irrigated farmland, prospects for irrigation, and fuel costs.

Keywords: Irrigation, energy, water use.

Additional Copies of This Publication . . .

Can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Include the title and series number in your order. Write to the above address for price information, or call the GPO order desk at (202) 783-3238. You may also charge your purchase by telephone to your VISA, MasterCard, Choice, or GPO Deposit Account. Bulk discounts available. Foreign customers, please add 25 percent extra for postage.

Microfiche copies (\$5.95 each) can be purchased from the National Technical Information Service, Identification Section, 5285 Port Royal Road, Springfield, VA 22161. Include the title and series number in your order. Enclose a check or money order payable to NTIS. For faster service, call NTIS at (703) 487-4780 and charge your purchase to your VISA, MasterCard, American Express, or NTIS Deposit Account.

The Economic Research Service has no copies for free distribution.

Contents

	Page
Summary	iii
Introduction	1
Irrigation Terminology	1
Survey Results	4
Payment-in-Kind	4
Area Irrigated	4
Distribution Systems	4
Types of Energy Used	4
Quantity of Energy Used	4
Costs of Energy Used	5
Observations and Implications	5
Growth of Pump Irrigation	5
Changing Energy Prices	6
Cost Reduction Alternatives	8
Efficiency	8
Reduced Water Use	9
Cheaper Energy Sources	9
References	10
Appendix I—Procedure	11
Appendix II—Tables	12
Appendix III—State Irrigation Specialists	42

Summary

U.S. farmers increased onfarm pump irrigation by 27 percent from 1974 to 1983, adding 9.5 million pump-irrigated acres. However, the increase was smaller during each successive 3-year period, including 1980 to 1983. Farmers irrigated 44.6 million acres in 1983 with onfarm pumps, and pump energy accounted for 23 percent of the total energy used on the farm for crop production. Electricity was the predominant energy source for irrigation pumps, followed by natural gas, diesel, liquefied petroleum gas (LPG), and then gasoline. Diesel fuel use more than doubled, but the use of gasoline and LPG for pumping irrigation water declined.

This report, the fourth in a series, updates the 1980 irrigation estimates and focuses on 1983 pump-irrigated farmland, prospects for irrigation, and fuel costs.

The cost of energy for onfarm pump irrigation nearly quadrupled, rising from \$551 million to nearly \$2 billion between 1974 and 1980, and then increased another \$0.5 billion between 1980 and 1983. These increases were due to more acreage irrigated and much higher energy prices. Natural gas prices rose 700 percent, diesel 330 percent, LPG 285 percent, and gasoline 281 percent. Electricity prices increased the least, but they more than doubled. Although most of the increase in energy prices occurred between 1974 and 1980, only natural gas prices increased significantly between 1980 and 1983, and the price of diesel declined slightly.

Pump irrigation use grew significantly despite the higher energy prices. The energy costs for pumping irrigation water constituted a small portion of the total crop-production costs in many pump-irrigation areas. Also, there were rather favorable crop prices during most of the 1974-83 period, which encouraged pump irrigation. Sales from irrigated farms accounted for 30 percent of overall farm sales in 1983, a 6-percent increase over 1974 sales.

Pump irrigators can reduce their energy costs by irrigating more efficiently. Tail-water recovery for surface-water irrigation systems has become very popular and can reduce energy use by 10 to 30 percent. Also, low-pressure center pivot sprinkler systems saved U.S. farmers an estimated \$72 million in energy costs during 1983.

If profitable, irrigation could expand by 3 to 4 million acres in the Great Plains by the year 2020. The eastern half of the United States, where irrigation grew by 8.2 million acres from 1974 to 1983, shows potential for gains in irrigation use. Soil and water resources are adequate to support an additional 18-20 million acres of irrigated land.

Energy and U.S. Agriculture

Irrigation Pumping, 1974-83

Gordon Sloggett*

Introduction

Land irrigated in the United States, with the aid of energy-using pumps on farms and ranches, increased from 35 million acres to 44.6 million acres from 1974 to 1983. According to the census of agriculture, all irrigated farms accounted for 24 percent of farm sales in 1974, 29 percent in 1978, and 30 percent in 1982. This increase reflects greater production from increased acreage.

This report examines the amount of U.S. farmland irrigated with onfarm pumps since 1974, the fuels used to power those pumps, and implications for future irrigation. This report is the fourth in a series begun in 1974 concerning energy used to pump and distribute irrigation water (18).¹ These estimates span the entire country, including farm production regions and individual States (fig. 1).

Energy used for pumping irrigation water was 23 percent of all onfarm energy used for agricultural production in 1974. Growth in pump irrigation, increasing energy prices, and changing energy price relationships have heightened the importance of the types, amounts, and geographical patterns of energy consumed in pumping irrigation water.

To estimate energy use, the study determined: (1) acreage irrigated from ground water and from pumped surface water, (2) feet of lift required for ground water and pumped surface water, (3) types of distribution systems used to apply water to fields, (4) types of power units used for pumping, and (5) acre-feet of water applied.² Estimates were also ob-

tained for pumping-unit efficiency and pressure needed to operate distribution systems. These factors were applied uniformly for all States.

Data used in making estimates for 1974, 1977, and 1980 were sent to State irrigation specialists for updating to 1983.³ Appendix I describes the procedures for estimating energy use. However, studies of energy used for irrigation became available for California, Idaho, Oregon, and Washington after the 1974 estimates were made. The 1974 estimates in those States were revised using the King and Knutson data (12, 13). Electricity consumption for Kansas irrigation pumping also employed other data (1).

The results presented in this report were based on estimates of statewide averages from various sources. The data were not the result of scientific sampling; therefore, no procedure was available to determine the statistical accuracy of the results. These data, however, are reasonable estimates of the extent of pump irrigation use. They indicate shifts in energy consumption from changes in types of energy used for pumping and in different types of irrigation distribution systems used.

Irrigation Terminology

The following information defines commonly used phrases in irrigation, outlines estimating procedures, and identifies sources of data.

Acreage irrigated from ground water. Water in aquifers, commonly referred to as ground water, must be pumped from wells for irrigation. Several States conducted surveys or used other procedures

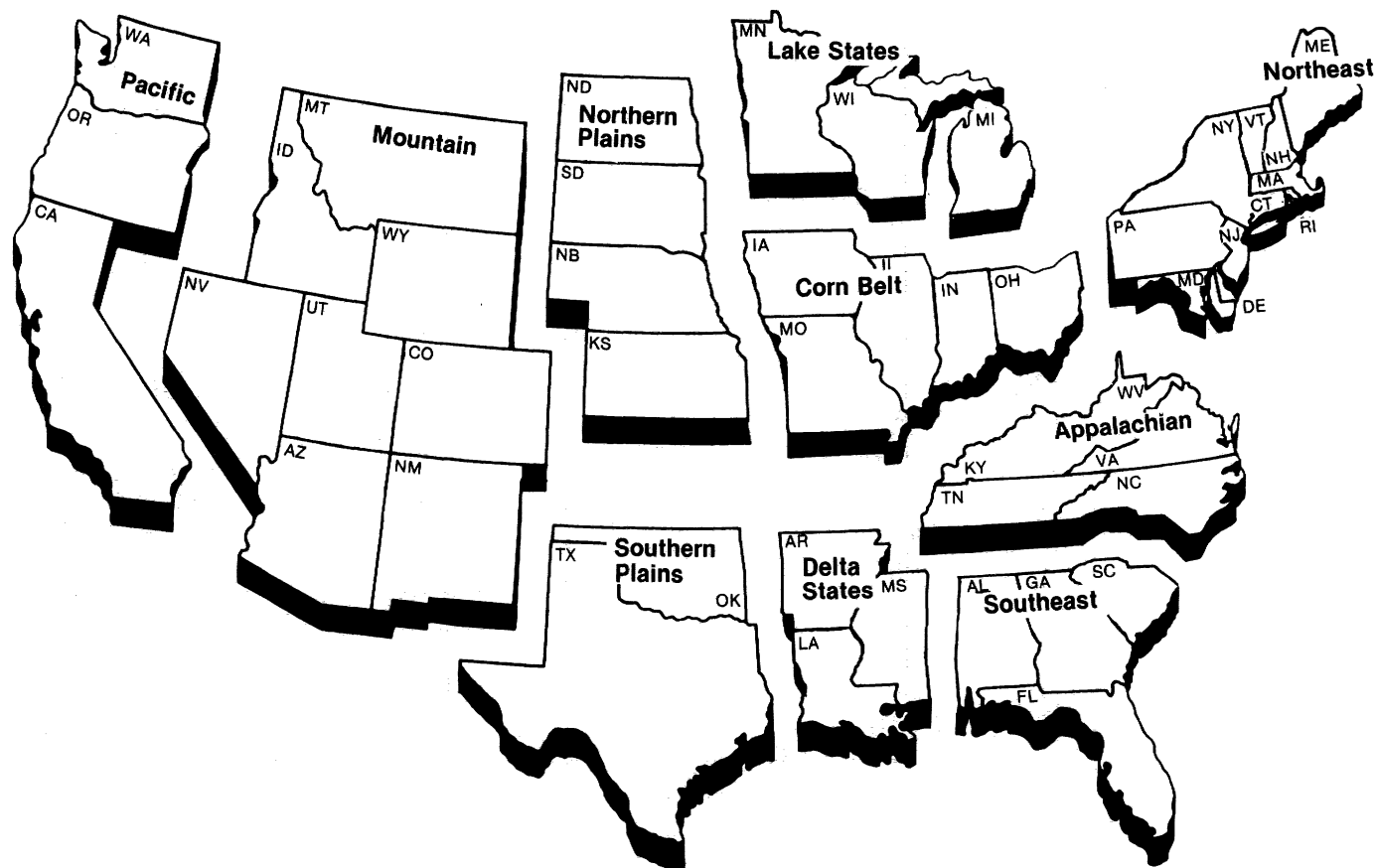
*The author is an agricultural economist with the Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture.

¹Italicized numbers in parentheses cite sources listed in the References section.

²An acre-foot is 1 foot of water applied over 1 acre.

³Irrigation specialists contacted for State estimates appear in appendix III.

Farm Production Regions



to estimate acreage irrigated from ground water. These estimates were used where available. Otherwise, the total acreage irrigated in 1974 came from the 1974 Irrigation Survey in the *Irrigation Journal* (9). The proportion of acreage irrigated from ground water, as published by the U.S. Geological Survey (USGS), was then multiplied by total acreage irrigated to estimate acreage irrigated from ground water in 1974 (16). Estimates for 1977, 1980, and 1983 were estimated from the 1974 base.

Acreage irrigated from pumped surface water. Surface water is in lakes, streams, or rivers. Although some of this water is pumped onto fields for irrigation, no data were available for acres irrigated in this manner. Therefore, each State irrigation specialist estimated how many acres were irrigated with water pumped from surface sources.

Feet of lift. Feet of lift measures the height water must be raised from its source to the field for application. State irrigation specialists estimated a weighted statewide average feet-of-lift figure for irrigation wells. The specialists also provided a weighted average feet-of-lift estimate for onfarm pumped surface water. The weight was approximate acreage irrigated according to pumping depths. Changes in feet of lift (app. table 1) in some of the States from 1974 through 1983 resulted from either actual changes as perceived by the irrigation specialists or from improved information upon which they based their estimates.⁴

⁴The estimates are subject to error, and changes in pumping lifts caused by declining water levels may or may not be reflected in the data provided by the irrigation specialists.

Distribution systems and power units. Major water distribution systems included various sprinkler and flooding methods used to distribute water to fields. Power units were run by electricity, diesel, gasoline, natural gas, and liquefied petroleum gas (LPG). Information on numbers of distribution systems and types of power units in the 1974 Irrigation Survey in the *Irrigation Journal* were used where available for the 1974 energy estimates.⁵ When this information was not available for 1974 and for all the 1977, 1980, and 1983 surveys, irrigation specialists estimated distribution system and power unit use.

Acre-feet applied. USGS data provided estimates of the quantity of water applied per acre, and each State irrigation specialist then reviewed the estimates (16). Several specialists offered alternative estimates and, in some instances, USGS data were modified.

Pumping unit efficiency. A new irrigation pump has an efficiency of about 75 percent (efficiency measures energy input to water output). Efficiency declines when pumping equipment wears down. Irrigation engineers in those States with significant ground water estimated the average operational pump efficiency. Since their estimates varied, coefficients for three pump efficiency ratings were used to provide three estimates of energy consumption (table 1).

An error was made in estimating energy requirements in 1974, 1977, and 1980 for pumping with electricity (see table 1). The new estimate is slightly lower, and 1974-80 electricity use has been adjusted downward to reflect the correction. Power units operating the pumps were assumed to be in average condition. All energy estimates in this report assumed a 60-percent water pump efficiency and that power units were in average operating condition. Energy consumption for 55-percent pump efficiency may be determined by increasing the 60-percent estimates by 7.62 percent. Estimates for 65-percent efficiency may be made by decreasing

the 60-percent estimates by 7.63 percent. All energy estimates in this report may be adjusted similarly.

Distribution system pressure requirements. State irrigation specialists established pounds per square inch (psi) requirements for various irrigation distribution systems. A middle range was selected because estimates varied:

Distribution system	psi
Big gun	165
Center pivot	100
Other sprinkler	70
Surface distribution	5

The estimates included the pressure required to overcome friction loss in the lines from the pump through the distribution system and to apply water to the land. Pressure requirements for various sprinkler systems are often quoted for only the nozzle pressure. The pressure required to operate the system was included with that needed to get the water to ground level.

Since 1977, a great deal of interest has focused on low-pressure center pivot irrigation systems. For the 1980 and 1983 data, State irrigation specialists estimated the percentage of the center pivots that were considered low-pressure systems and at which pressure they operated. The average pressure required to operate the low-pressure systems was about 35 psi. The estimated area of center pivot and of low-pressure center pivot irrigation systems for each State is shown in appendix table 8. Energy consumption estimates for 1980 and 1983 included ad-

Table 1—Fuel energy requirements for pumping 1 acre-foot of water at 1 pound per square inch (psi)

Energy	Horsepower hours ¹	Percentage of efficiency		
		65	60	55
Unit fuel per acre-foot per psi				
Electricity	1.206 per kWh	4.0503	4.3876	4.7866
Diesel	12.35 per gallon	.4000	.4330	.4659
Gasoline	9.875 per gallon	.5004	.5417	.5830
Natural gas	79 per MCF ²	.0625	.0677	.0729
LPG	7.9 per gallon	.6254	.6771	.7287

¹This column refers to the assumed number of horsepower hours produced per unit of fuel.

²MCF equals 1,000 cubic feet.

Source: Material provided by Delbert Schwab, agricultural engineer, Oklahoma State University, Stillwater.

⁵It was necessary to assume that each type of power unit pumped an equal amount of water in order to estimate area irrigated by type of energy. However, in States where natural gas is used extensively, those wells typically irrigated more acreage than did non-natural-gas-powered wells. *Irrigation Journal* estimates of power units were percentages of each type. Therefore, data were adjusted to increase acreage irrigated with natural-gas-powered wells in Arizona, Kansas, New Mexico, and Texas. The remaining acreage in those States was then divided proportionately with *Irrigation Journal* figures.

justments in the energy estimation model for low-pressure center pivot systems (see app. I).

Survey Results

This report highlights national, State, and regional irrigation survey results. Energy estimates were based on the number of acres irrigated with pumped water and the quantity of water pumped. Appendix table 10 summarizes several irrigated acreage estimates in the United States. Many of the same irrigation specialists who provided data to the *Irrigation Journal* provided the data in this report. The *Irrigation Journal* estimates were among the higher estimates of irrigated acreage. Thus, estimates of irrigated acreage and subsequent energy estimates in this report may be higher than estimates based on other sources.

Payment-in-Kind

The USDA Payment-in-Kind (PIK) program, which encouraged farmers to reduce their acreage of wheat, cotton, rice, and feed grains during crop year 1983, affected a significant amount of irrigated land. However, to reduce the distortion in the data from 1974 to 1983, irrigation specialists estimated how much land would have been irrigated without the PIK program, and what percentage of the pump-irrigated land was not irrigated due to the program. All of the data in this report reflect what pump irrigation would have been without the PIK program. Appendix table 9 presents State estimates of pump-irrigated acreage under the PIK program. About 12 percent of the U.S. pump-irrigated land was taken out of production for the PIK program in 1983.

Area Irrigated

The area irrigated with pumped water increased by 27 percent from 1974 to 1983 (table 2). The change between 1980 and 1983 was the smallest 3-year change in the study and may signify a slowing in the growth of irrigation use. Ground water caused much of the increase, but land irrigated with both ground water and surface water increased most rapidly. Pump irrigation in the Corn Belt and Lake States grew much faster than in other regions of the country (table 3). However, the Northern Plains and the Southeast regions experienced the largest growth in irrigated land. The Texas High Plains of the Southern Plains region, where the Ogallala aquifer is becoming depleted, had a slight decline in pump-irrigated land from 1974 to 1983.

Distribution Systems

Big gun sprinklers brought the largest percentage increase in irrigation among types of water distribution systems (table 4). Center pivots provided the largest increase in acreage irrigated, 5.5 million acres from 1974 to 1983. Nebraska experienced a million-acre increase in center pivot irrigation from 1974 to 1983, according to the University of Nebraska's Remote Sensing Center. Sprinkler irrigation accounted for 84 percent of the overall increase in irrigation for the period.

Acres irrigated with gravity distribution systems had the smallest percentage increase in irrigation from 1974 to 1983. These systems, generally the least expensive method of irrigating, were the first to be developed. They require relatively flat, non-sandy land and an adequate water supply. Most of the areas in the Nation that can benefit from irrigation and have these two attributes developed systems before 1974. During the sixties and seventies, the widespread adoption of automatic sprinkler systems, such as center pivots, big gun, and side roll, took place on rolling or sandy land with adequate water supplies for irrigation.

Types of Energy Used

Acreage where electricity, diesel, and natural gas were used to pump irrigation water increased during 1974-83, while acreage where gasoline and LPG were used declined (table 5). The trend is unmistakable. The irrigated areas using diesel grew most rapidly, followed by electricity and natural gas. Natural gas use declined between 1980 and 1983—primarily in the Texas and Oklahoma Panhandles—because of sharply higher prices and declining water supplies.

Natural gas is usually the least expensive fuel for pumping irrigation water, but it is not available in many areas. Electricity is usually the next best alternative. Many electric utilities are operating at capacity, however, and are not anxious to add to peak loads with more irrigation customers. There was no shortage of diesel fuel or engines; and being the next preferred source of energy, diesel fuel use increased the most rapidly from 1974 to 1983.

Quantity of Energy Used

The overall increase in energy used for onfarm pump irrigation reflected not only the 9.5-million-acre increase in acreage irrigated but also a

Table 2—Acreage irrigated with onfarm pumped water, by source of water

Source of water	1974	1977	1980	1983 ¹	Change, 1974-83	Percentage change, 1974-83
	-----Million acres-----					Percent
Ground water	25.6	30.0	31.6	33.1	7.5	29
Surface water	7.3	8.0	7.9	8.2	.9	12
Acreage with both sources	2.2	2.3	3.1	3.3	1.1	50
Total	35.1	40.3	42.6	44.6	9.5	27

¹See discussion of Payment-in-Kind on p. 4.**Table 3—Regional changes in acreage irrigated with onfarm pumped water, 1974-83**

Farm production region	1974	1983 ¹	Change, 1974-83	Percentage change, 1974-83
	-----1,000 acres-----			Percent
Northeast	292	329	37	13
Lake States	411	1,269	858	209
Corn Belt	370	990	620	168
Northern Plains	7,250	11,594	4,344	60
Appalachia	192	344	152	79
Southeast	2,041	3,858	1,817	89
Delta States	2,688	3,760	1,072	40
Southern Plains	9,517	8,523	- 994	- 10
Mountain	6,020	6,574	554	9
Pacific	6,286	7,334	1,048	17
Alaska	7	2	- 5	71
Hawaii	76	86	10	13
Total	35,150	44,663	9,513	27

¹See discussion of Payment-in-Kind on p. 4.

greater use of sprinklers. Sprinklers irrigated 86 percent of the increased acreage, although they used more energy than gravity-flow irrigation systems used. Diesel use increased more than other energy sources (table 6).

Costs of Energy Used

The 352-percent increase in spending for energy for onfarm pumping of irrigation water from 1974 to 1983 centered on higher prices and increased energy use (table 7). About \$1.4 billion (74 percent) of the \$1.9-billion increase in pumping costs can be attributed to higher prices. The prices of all forms of energy increased sharply after the first oil embargo.

Observations and Implications

The irrigated acreage and energy cost increases between 1974 and 1983 led to: the feasibility of further expansion of pump irrigation in the face of declining water levels in certain areas, the effect of even higher energy prices, and irrigator reaction to both issues.

Growth of Pump Irrigation

Declining water levels and increased energy costs will likely inhibit the growth of irrigation. Ground water is declining steadily under 16 million irrigated acres of U.S. farmland (19). One of the major areas of ground-water decline was the Texas High Plains in the Southern Plains region, where about 5 million acres were irrigated, after a decline of about 1 million acres from 1974 to 1983 (table 3). Analysts estimate that over half of the High Plains water supply will be depleted by the year 2020 (25). The pump-irrigated area in the Texas High Plains will continue to decline, and pump irrigation in some of the other ground-water decline areas will probably begin decreasing before the turn of the century.

While pump irrigation will eventually decrease in the ground-water decline areas, favorable economic conditions caused pump irrigation to increase where adequate water supplies and proper soil and climatic conditions exist. An intergovernmental agency task force identified 26 million potentially irrigable acres in the Eastern United States (11). Although that potential may not be fully realized, pump irrigation increased by 4.5 million acres in the eastern farm production regions from 1974 to 1983 (table 3). Considerable expansion of pump irrigation is possible in the eastern half of the United States, given continued favorable economic conditions.

The Economic Development Administration's study of the declining Great Plains Ogallala aquifer indicated an increase of 3.5 million irrigated acres by the year 2020 under favorable economic, technological, and agronomic conditions (15). Irrigation from the Ogallala aquifer will eventually decline because more water is being withdrawn than is naturally being returned; nonetheless, potential for near-term expansion exists.

Changing Energy Prices

Energy prices increased from 182 percent for electricity to 700 percent for natural gas from 1973 to 1983 (table 8). Natural gas showed the largest percentage increase in price, but it remains the lowest cost fuel for pumping irrigation water (table 9). However, price relationships among types of energy changed dramatically between 1973 and

Table 4—Acreage irrigated with onfarm pumped water, by type of distribution system

Distribution system	1974	1977	1980	1983 ¹	Change, 1974-83	Percentage change, 1974-83
-----Million acres-----						Percent
Big gun	0.6	1.3	1.9	2.0	1.4	233
Center pivot	3.7	6.2	8.1	9.2	5.5	148
Other sprinkler	7.6	8.1	8.4	8.9	1.3	17
Gravity	23.2	23.9	24.4	24.5	1.3	6
Total	35.1	39.5	42.8	44.6	9.5	27

¹See discussion of Payment-in-Kind on p. 4.

Table 5—Acreage irrigated with onfarm pumped water, by type of energy

Energy	1974	1977	1980	1983 ¹	Change, 1974-83	Percentage change, 1974-83
-----Million acres-----						Percent
Electricity	15.8	18.2	20.4	21.8	6.0	38
Diesel	3.9	6.8	7.7	8.5	4.6	118
Gasoline	1.5	1.2	1.0	.9	-.6	-40
Natural gas	10.6	10.9	11.1	10.8	.2	2
LPG	3.3	2.4	2.6	2.6	-.7	-21
Total	35.1	39.5	42.8	44.6	9.5	27

¹See discussion of Payment-in-Kind on p. 4.

Table 6—Quantity of energy used for onfarm pumped irrigation water

Fuel	Unit	1974	1977	1980	1983	Change, 1974-83	Percentage change, 1974-83
-----Units of fuel-----							Percent
Electricity	Bil. kWh	16	19	21	23	7	44
Diesel	Mil. gal.	184	360	429	530	346	188
Gasoline	Mil. gal.	67	72	61	57	- 10	- 15
Natural gas	Mil. MCF	129	143	146	144	15	12
LPG	Mil. gal.	238	234	254	257	19	8

1983, affecting the relative cost of pumping. In 1973, little cost difference separated electricity and diesel energy for pumping, and natural gas was from 65 to 75 percent cheaper than diesel or electricity. By 1983, the cost of electricity for pumping was 32 percent less than the cost of diesel, and natural gas was only 5 percent cheaper than electricity. Natural gas still is cheaper than electricity, but the gap is narrowing rapidly. Natural gas is not available in many pump irrigation areas, and in those areas, electricity has a clear price advantage over diesel.

Although rising energy prices affected the cost of pumping irrigation water, irrigation continues to expand because commodity prices also increased (table 9). The seasonal average U.S. price per bushel for corn was \$2.38 in 1973 and \$3.30 in 1983. Assuming a 130-bushel yield, gross receipts would have increased by \$119.60 per acre $\{(\$3.30 - \$2.38) \times 130\}$ between 1973 and 1983. The only example in table 9 where increased energy costs would not be covered by increased revenue was the

diesel-powered center pivot in the Oklahoma Panhandle. The increased energy cost for the more common natural gas-powered systems in the Oklahoma Panhandle was \$99 compared with increased revenues of \$119.60. In the Nebraska examples, increased revenues offset all of the increased pump energy costs.

Production costs other than irrigation fuel have also increased. Gross receipts for irrigated corn with a 130-bushel yield at \$3.30 would be \$429. The production costs shown in table 9 do not include a charge for land and management; but in the Oklahoma Panhandle, revenue did not allow for returns to land and management for any of the center pivot examples or for the gravity-flow diesel example. This is reflected in a 100,000-acre decline in irrigated acreage in Oklahoma between 1980 and 1983 (app. table 2). Part of the decline in irrigation in Texas and New Mexico during the same period may be attributed to higher production and energy costs. Use of pump irrigation increased or remained stable in the rest of the Nation, indicating favorable economic conditions for most pump irrigators.

Table 7—Total cost of energy for onfarm pumping of irrigation water

Energy	1974	1977	1980	1983	Change, 1974-83	Percentage change, 1974-83
Million dollars						Percent
Electricity	288	551	926	1,152	864	300
Diesel	66	160	432	523	457	692
Gasoline	32	38	70	68	36	112
Natural gas	97	80	368	550	453	467
LPG	68	81	153	196	128	188
Total	551	910	1,949	2,489	1,938	352

Table 8—Selected energy prices in the United States

Item	Unit	1973	1974	1977	1980	1983	Percentage change, 1973-80
Dollars per unit							Percent
Electricity	kWh	0.023	0.027	0.035	0.055	0.065	182
Diesel	Gal.	.23	.37	.45	1.00	.99	330
Gasoline	Gal.	.33	.47	.57	1.17	1.26	281
Natural gas ¹	MCF	.50	1.00	1.50	2.50	4.00	700
LPG	Gal.	.20	.30	.39	.62	.77	285

¹Estimated.

Source: (22).

Table 9—Production costs per acre for irrigated corn in Nebraska and Oklahoma

Item	South-central Nebraska		Oklahoma Panhandle	
	Gravity flow	Center pivot	Gravity flow	Center pivot
<i>Dollars</i>				
Production costs ¹	281	274	340	343
Irrigation fuel costs: ²				
Electricity—				
1973	9	18	23	42
1983	24	52	64	118
Diesel—				
1973	8	18	23	41
1983	36	77	97	179
Natural gas—				
1973	3	6	8	14
1983	23	49	61	113

¹Exclusive of irrigation fuel, land charges, overhead, and management.

²Prices from table 8. Feet of lift was 100 feet for Nebraska and 250 feet for Oklahoma.

Sources: Nebraska (24); Oklahoma (17).

Cost Reduction Alternatives

Pump irrigators have little control over crop or energy prices, and they cannot be sure that crop prices will continue to cover projected increases in energy costs. They do, however, have some alternatives to offset the increasing energy costs. They can: use more efficient irrigation methods that use less water and energy, grow crops that use less water, use a less expensive energy source, or stop irrigating.

Efficiency

Many pump irrigators could reduce energy use by irrigating more efficiently through scheduling, using tail-water pits, or employing more efficient application systems. Irrigators may also reduce energy use by improving the mechanical efficiency of their pumping equipment.

Scheduling is a procedure that considers current evapotranspiration rates, rainfall, and soil moisture to determine the proper irrigation-water requirements of the crop. Traditionally, irrigation applications were predetermined with little attention paid to current climatic conditions. Scheduling could potentially reduce irrigation-water use by 20 to 30 percent, but unpredictable weather and labor and mechanical problems would likely cut water

savings to around 10 percent (8). A 10-percent reduction in water use would lead to an equivalent energy savings.

Tail-water pits also increase irrigation efficiency. A pit is dug at the low point of a gravity-irrigated field. Water that otherwise runs off the field is caught in the pit and recirculated through the irrigation system. The amount of water pumped from the ground can be reduced from 10 to 30 percent with a tail-water pit, depending upon the soil type, slope of the field, and other physical factors. Energy savings are not the equivalent of the water savings because water must be pumped from the pit. However, the energy savings can be significant because feet of lift from the pit is usually substantially less than from the original source.

No estimates were available concerning the extent of scheduling and tail-water pit adoption by pump irrigators. Several State and private organizations offer scheduling services and, because of rising energy prices, those services have become popular. Tail-water pits are mandatory in some States, and rising energy prices have also made them a popular conservation measure.

Low-pressure center pivot irrigation systems require less energy than do standard center pivot systems and are often mentioned as an energy-saving alternative. Standard systems can be converted to low pressure, and, of course, new center pivots can be ordered with the low-pressure option. However, low-pressure center pivot systems require soils with a high water-intake rate and low rates of slope to prevent runoff. Thus, not all center pivot applications can be low pressure.

An estimated 24 percent of the center pivot systems in place were low pressure in 1983 (app. table 8). Manufacturers of center pivots reported that 40 to 80 percent of their sales in 1980 were low-pressure systems (3). That trend appears to be continuing. The average low-pressure system required about 35 psi to operate, compared with 100 psi needed by high-pressure systems.

The energy savings from the low-pressure center pivot systems were estimated by using the energy estimation model in appendix I and variously assuming: no low pressure, the in-place situation, and all low pressure. In-place systems saved \$72 million in 1983. If all center pivots had been low pressure, the savings would have been \$305 million. Of course, not all center pivots can be converted to low pressure, but the potential exists for additional savings.

A pumping unit basically includes a powerplant and a pump. The powerplant can be an electric motor or an internal combustion engine. An electric motor maintains a rather constant efficiency throughout its useful life with little maintenance. An internal combustion engine requires periodic maintenance to prevent significant reductions in efficiency. An improperly maintained internal combustion engine can easily operate at 50 percent of attainable efficiency. A water pump also requires periodic maintenance to maintain peak efficiency.

A properly designed water pump can operate at 75- to 80-percent efficiency. However, various studies indicated that irrigation pumps in the United States operate at an average of 55- to 60-percent efficiency (5, 7, 14). While a 20-percent improvement appears possible, another study indicated that a 10-percent improvement would be a more realistic possibility (6). The energy-use estimates in this report assumed a 60-percent pump efficiency. A 10-percent improvement in pump efficiency would result in a 15.3-percent reduction in energy use (see table 1), amounting to a savings of \$380 million in 1983.

While it appears that pump irrigators have several opportunities to reduce energy costs, all of the alternatives carry additional costs. Scheduling requires more management, labor, and some equipment. Tail-water pits require construction and maintenance as well as a power unit, pump, and pipes. Retrofitting center pivots to low-pressure systems requires conversion and a possible change in the power unit and pump. Improving pumping plant efficiency requires additional maintenance. The pump irrigators' decision to take advantage of energy-saving alternatives depends upon the profitability of making a change. Rapidly rising energy prices accelerate the process.

Reduced Water Use

Farmers who irrigate efficiently, though losing ground to higher energy prices, may switch to a crop that requires less water. A typical crop change in the Great Plains would substitute sorghum for corn. The pump irrigators' decision to change to another crop would depend upon the relative profitability of the alternate crop and the equipment complement needed for that crop.

Cheaper Energy Sources

Changing to another energy source involves several factors other than price, including accessibility to

the source, future availability of that source, and the capital cost of changing. Electricity and natural gas provide some accessibility problems for pump irrigators. The type of electricity and powerlines needed for large pump motors are not always available at the well site. Erecting a powerline increases capital costs and may eliminate any economic advantages of shifting to electric power. Only those pump irrigators who have access to pipelines can choose natural gas as an alternate energy source, but many pump-irrigation areas of the Nation do not have natural gas pipelines. Regions that have access to pipelines generally use natural gas, because it is the least expensive energy source for pump irrigators. However, electricity prices are rapidly becoming competitive with natural gas prices.

The decision to change energy sources also depends upon future availability of that source, even if the pump irrigator is located close to all possible energy sources. Many electric utilities are operating at or near full capacity. Pump irrigators add to peak load periods, which inhibits some electric utilities from adding irrigators to the nearly full generating capacity. Many utilities place an annual limit on the number of new irrigators added to the distribution system. Thus, electricity may not be available to all pump irrigators.

Natural gas for irrigation is a special case because the Federal Government regulates its use. Some have proposed reducing the priority for irrigation into an interruptible-service classification which would allow gas companies to stop service to irrigators during peak summer periods. Yields could decline significantly because of interrupted service during the peak irrigation season.

Capital investment, or disinvestment, also influences the decision to change energy sources. A pumping plant, replaced because of high energy costs, would have little salvageable value, reflecting little demand for such a unit.

A detailed analysis of pump irrigation, including irrigation system selection, responses to rising energy costs, and power plant and irrigation system conversion potentials is available in (2). That report describes the various energy alternatives available to pump irrigators, including changes in energy prices and price relationships, distribution systems, pumping depths, and other factors. The reader should consult this source for an analysis of energy cost-saving conversion possibilities.

References

1. Anschutz, John A. "Summary of 1980 Electrical Pumping Loads in Kansas." Dept. Agr. Engr., Kansas State Univ., Manhattan.
2. Benson, V., C.A. Everson, and R.L. Sharp. *Irrigation Systems Selection or Conversion in an Energy-Short Economy*. ERS-670. U.S. Dept. Agr., Econ. Res. Serv., Nov. 1981.
3. Buckingham, Frank. "Cutting Pressure May Be the Answer." *Irrigation Age*. Feb. 1980, p. 10.
4. *Census of Agriculture, 1982*. U.S. Dept. Comm., Bureau of the Census.
5. Gilley, James, and Darrel Watts. *Possible Energy Savings in Irrigation*. ASCE Vol. 103, No. IR4. Dec. 1977, pp. 445-57.
6. Halderman, Allen D. *Irrigation Pumping Plant Field Performance*. Agr. Engr. and Soil Sci., College of Agr., Univ. of Arizona, Tuscon, 1978.
7. Hamrich, J.R. *Efficiency Improvements in Irrigation Well Pumps*. ASAE natural energy symposium, Kansas City, Kans., Oct. 1980.
8. Helluckson, Martin, and Marshall English. *Present and Future Irrigation Energy Use and Conservation*. ASAE natural energy symposium, Kansas City, Kans., Oct. 1980.
9. *Irrigation Journal*. Brantwood Publications, Inc., Elm Grove, Wisc., Nov.-Dec. 1974.
10. _____. Nov.-Dec. 1983.
11. *Irrigation Water Use and Management—Interagency Task Force*. U.S. Govt. Print. Off., June 1979, p. 107.
12. King, Larry, and others. *Energy and Water Consumption of Pacific Northwest Systems*. BNWL-RAP-19-UC-11. Dept. Agr. Engr., Oregon State Univ., Corvallis, Aug. 1978.
13. Knutson, G.D., and others. *Pumping Energy Requirements for Irrigation in California*. Special Publication No. 3215. Div. Agr. Sci., Univ. of California, Davis, July 1977.
14. Longerbaugh, Robert. *Irrigation Pump Efficiency and Its Impact on Conservation*. Western Irrigation Forum, Denver, Colo., Mar. 1979.
15. Mapp, Harry. *The Six State Ogallala Aquifer Area Study: Baseline Results for the Agricultural Sector*. Oklahoma Agr. Exp. Sta., Oklahoma State Univ., Stillwater, July 1981.
16. Murray, C. Richard, and E. Bodette Reeves. *Estimated Use of Water in the U.S. in 1970*. USGS Circular 676. U.S. Dept. Int., U.S. Geological Survey, 1972, pp. 22-23.
17. Oklahoma State University, Department of Agricultural Economics, Budget Record No. 72100767, 72100860, 1980.
18. Sloggett, Gordon R. *Energy and U.S. Agriculture: Irrigation Pumping, 1974-80*. AER-495. U.S. Dept. Agr., Econ. Res. Serv., Dec. 1982.
19. _____. *Prospects for Ground-Water Irrigation: Declining Levels and Rising Energy Costs*. AER-478. U.S. Dept. Agr., Econ. Res. Serv., Dec. 1981.
20. Torgerson, David, and Harold Cooper. *Energy and U.S. Agriculture: 1974 and 1978*. SB-632. U.S. Dept. Agr., Econ. Res. Serv., Apr. 1980.
21. U.S. Department of Agriculture, Soil Conservation Service, *National Resource Inventory, 1982*.
22. U.S. Department of Agriculture, Statistical Reporting Service, *Agricultural Statistics, 1974-84*.
23. U.S. Geological Survey, *Estimated Use of Water in the United States, 1980*. preliminary data.
24. University of Nebraska, Agricultural Economics Extension Staff, "Estimated Crop and Livestock Production Budgets." Lincoln, IEC 79-872, 1980.
25. Wyatt, A.W. *TWDB High Plains Study*. Texas Water Devel. Board, Austin, Sept. 1974.

Appendix I—Procedure

The method used to estimate energy used for irrigation determined how much water was pumped, and how much effort, or work, was required to pump and distribute that amount of water. The next step determined how much energy was needed to perform that amount of work for ground water and surface water.

The quantity of water pumped in each State was determined as follows:

$$AF_i = (AI_i) (AFA_i) \quad (1)$$

where:

AF_i = acre-feet of water used from ground water (pumped surface water) sources in i th State,

AI_i = acres irrigated from ground water (pumped surface water) in i th State, and

AFA_i = average annual acre-feet applied per acre in i th State.

$$i = 1, \dots, 50$$

The work required to pump the water to ground level was measured in psi. The psi is determined by dividing the feet of lift by 2.31. The total work (acre-feet psi) required to get the ground water to the surface in each State was determined by:

$$TPW_i = (AF_i) (PW_i) \quad (2)$$

where:

TPW_i = total work required to get water to ground level in the i th State,

AF_i = equation (1), and

PW_i = psi required to get water to ground level for the average feet of lift in the State.

$$i = 1, \dots, 50$$

Work required to distribute ground water (pumped surface water) in each State was estimated as follows:

$$TPD_i = AF_i \sum_{j=1}^4 (DP_{ij}) (PD_j), \quad (3)$$

where:

$$i = 1, \dots, 50 \text{ States}$$

$$j = 1, \dots, \text{four types of irrigation systems,}^1$$

where:

TPD_i = total work required to distribute ground water (pumped surface water) in the i th State,

AF_i = equation (1),

DP_{ij} = percentage of acres irrigated in i th State by j th system, and

PD_j = pressure required to operate j th system.

The sum of equation (2) plus equation (3) is the total work (acre-feet psi) required to irrigate with ground water (pumped surface water) in a State. The amount of energy consumed to pump and distribute the irrigation water by each energy source is estimated as follows:

$$ER_{ij} = \{TPW_i + TPD_i\} \{(ET_{ij}) (ETR_j)\}, \quad (4)$$

$$i = 1, \dots, 50 \text{ States}$$

$$j = 1, \dots, \text{five types of power units,}$$

where:

ER_{ij} = energy required in i th State by the j th power unit,

TPW_i and TPD_i = equations (2) and (3),

ET_{ij} = proportion of acres irrigated in i th State with j th power units,

ETR_j = amount of fuel required to pump 1 acre-foot of water at one psi with j th power unit.

Equation (4) assumes that the various distribution systems use equal proportions of the types of power units in the State; that is, sprinkler systems power units are distributed proportionally the same as gravity-flow power units.

¹In States with low-pressure center pivot systems,

$$PD_2 = \{(PH) (100)\} + \{(PL) (35)\},$$

where:

PH = the percent of high-pressure center pivots, and

PL = the percent of low-pressure center pivots.

Appendix II—Tables

Appendix table 1—Feet of lift required for onfarm pumping and acre-feet of irrigation water applied by source and by region and State¹

Region and State	Ground water				Surface water				Acre-feet applied
	1974	1977	1980	1983	1974	1977	1980	1983	
	----- Feet of lift -----								Acre-feet
Northeast:									
Connecticut	80	80	80	20	20	20	20	20	0.42
Delaware	50	50	50	50	20	15	15	15	.58
Maine	0	0	15	15	15	15	15	15	.20
Maryland	50	20	25	30	50	20	25	25	1.00
Masachusetts	80	80	80	80	10	10	10	10	.42
New Hampshire	0	0	0	0	20	20	20	20	.42
New Jersey	175	175	175	100	20	20	20	15	.60
New York	80	80	80	80	25	25	25	25	.42
Pennsylvania	150	150	150	150	35	30	30	30	.42
Rhode Island	0	0	0	0	20	20	20	20	.42
Vermont	0	0	0	0	20	20	20	20	.42
Lake States:									
Michigan	100	100	100	100	20	20	20	20	.67
Minnesota	70	70	80	80	10	10	10	10	.75
Wisconsin	75	75	75	75	20	15	15	15	1.25
Corn Belt:									
Illinois	55	55	55	55	0	15	15	15	.50
Indiana	150	150	125	125	25	25	15	15	.70
Iowa	35	35	40	40	25	15	15	15	.75
Missouri	75	75	75	75	25	25	25	25	.50
Ohio	100	100	100	100	25	25	25	25	.50
Northern Plains:									
Kansas	180	180	190	190	15	15	15	15	1.70
Nebraska	100	100	100	100	20	20	20	20	1.75
North Dakota	75	75	75	75	35	35	35	35	1.00
South Dakota	70	80	120	120	150	150	130	130	1.25
Appalachia:									
Kentucky	75	75	75	75	25	25	25	25	.33
North Carolina	150	150	150	150	35	35	15	12	.50
Tennessee	100	100	100	100	25	25	25	25	.90
Virginia	12	12	12	100	30	30	30	30	.80
West Virginia	0	0	0	0	25	25	25	25	.45

See footnotes at end of table.

Continued—

Appendix table 1—Feet of lift required for onfarm pumping and acre-feet of irrigation water applied by source and by region and State¹—Continued

Region and State	Ground water				Surface water				Acre-feet applied
	1974	1977	1980	1983	1974	1977	1980	1983	
	Feet of lift								Acre-feet
Southeast:									
Alabama	150	150	150	150	40	40	100	100	0.60
Florida	85	95	95	97	5	6	7	7	1.20
Georgia	250	250	250	150	15	15	15	15	1.30
South Carolina	100	100	100	110	20	20	20	30	.80
Delta States:									
Arkansas	45	60	90	93	15	15	15	15	1.83
Louisiana	100	100	100	100	10	10	10	10	1.83
Mississippi	110	50	50	50	15	15	15	15	2.00
Southern Plains:									
Oklahoma	200	200	200	200	20	16	16	16	1.83
Texas	200	200	210	215	40	40	40	40	1.50
Mountain:									
Arizona	350	375	400	425	0	0	0	0	5.40
Colorado	115	120	125	125	10	10	10	10	1.10
Idaho	266	266	225	280	0	11	12	13	3.20
Montana	100	100	100	100	60	60	60	60	2.70
Nevada	100	100	100	100	20	20	20	20	5.00
New Mexico	250	250	260	265	5	5	5	5	2.75
Utah	225	225	225	225	15	15	15	15	2.75
Wyoming	150	150	150	150	25	25	25	25	1.83
Pacific:									
California	110	110	135	140	10	10	10	10	3.17
Oregon	266	266	266	266	11	11	11	11	3.00
Washington	287	287	270	270	26	26	26	26	4.20
Alaska	100	100	100	100	10	10	10	10	.25
Hawaii	700	700	700	700	10	10	10	10	6.00

¹Estimated statewide average weighted by number of wells at each depth.

Appendix table 2—Acreage irrigated with onfarm pumped water, by source and region and State

Region and State	Ground water				Surface water				Both				Total			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres																
Northeast:	137	153	166	171	155	151	154	158	0	0	0	0	292	304	320	329
Connecticut	1	2	1	1	8	10	7	7	0	0	0	0	9	12	8	8
Delaware	20	26	35	35	6	4	7	7	0	0	0	0	26	30	42	42
Maine	0	0	0	0	7	7	7	7	0	0	0	0	7	7	7	7
Maryland	8	17	22	27	16	16	18	22	0	0	0	0	24	33	40	49
Massachusetts	1	1	1	1	31	31	31	31	0	0	0	0	32	32	32	32
New Hampshire	0	1	0	0	6	7	7	7	0	0	0	0	6	7	7	7
New Jersey	75	75	75	75	30	30	30	30	0	0	0	0	105	105	105	105
New York	30	30	30	30	29	24	25	25	0	0	0	0	59	54	55	55
Pennsylvania	2	2	2	2	17	17	17	17	0	0	0	0	19	19	19	19
Rhode Island	0	0	0	0	3	3	3	3	0	0	0	0	3	3	3	3
Vermont	0	0	0	0	2	2	2	2	0	0	0	0	2	2	2	2
Lake States:	253	605	906	1,007	158	146	248	262	0	0	0	0	411	751	1,154	1,269
Michigan	56	56	234	253	53	53	137	148	0	0	0	0	109	109	371	401
Minnesota	82	352	430	454	50	45	61	64	0	0	0	0	132	397	491	518
Wisconsin	115	197	242	300	55	48	50	50	0	0	0	0	170	245	292	350
Corn Belt:	274	490	751	787	96	135	172	191	0	7	7	12	370	632	930	990
Illinois	50	40	129	129	0	13	13	13	0	0	0	0	50	53	142	142
Indiana	19	36	55	70	14	20	28	43	0	2	2	3	33	58	85	116
Iowa	50	150	227	235	7	15	15	15	0	0	0	0	57	165	242	250
Missouri	143	248	324	340	55	57	86	103	0	5	5	9	198	310	415	452
Ohio	12	16	16	13	20	30	30	17	0	0	0	0	32	46	46	30
Northern Plains:	6,380	8,977	10,130	10,690	684	676	710	714	186	185	190	190	7,250	9,838	11,030	11,594
Kansas	2,230	3,073	3,489	3,489	65	75	85	85	10	10	15	15	2,305	3,158	3,589	3,589
Nebraska	4,074	5,670	6,316	6,850	505	440	440	440	176	175	175	175	4,755	6,285	6,931	7,465
North Dakota	33	85	127	141	23	11	11	15	0	0	0	0	56	96	138	156
South Dakota	43	149	198	210	91	150	174	174	0	0	0	0	134	299	372	384
Appalachia:	17	23	25	27	175	107	265	315	0	3	10	2	192	223	200	344
Kentucky	1	1	1	1	26	26	26	29	0	0	0	0	27	27	27	30
North Carolina	5	7	3	11	104	110	150	185	0	3	10	2	109	120	163	198
Tennessee	6	7	10	12	11	12	15	18	0	0	0	0	17	19	25	30
Virginia	3	3	11	3	31	47	63	82	0	0	0	0	36	55	74	85
West Virginia	0	0	0	0	3	2	1	1	0	0	0	0	3	2	1	1

Continued—

Appendix table 2—Acreage irrigated with onfarm pumped water, by source and region and State—Continued

Region and State	Ground water				Surface water				Both				Total			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres																
Southeast:	1,058	1,343	2,178	2,437	980	1,359	1,285	1,316	3	8	14	105	2,041	2,710	3,477	3,858
Alabama	8	25	35	43	17	30	95	112	0	5	10	0	25	60	140	155
Florida	960	1,076	1,450	1,610	823	960	817	840	0	0	0	0	1,783	2,036	2,267	2,450
Georgia	80	230	663	725	114	347	323	294	0	0	0	100	194	577	986	1,119
South Carolina	10	12	30	59	26	22	50	70	3	3	4	5	39	37	84	134
Delta States:	1,466	1,486	1,837	2,733	722	676	525	460	500	500	675	567	2,688	2,662	3,037	3,760
Arkansas	900	900	1,075	1,770	296	300	75	63	500	500	675	567	1,696	1,700	1,825	2,400
Louisiana	340	284	395	405	332	276	350	355	0	0	0	0	672	560	745	760
Mississippi	226	302	367	558	94	100	100	42	0	0	0	0	320	402	467	600
Southern Plains:	7,700	7,448	7,091	6,618	1,491	1,569	1,215	1,193	256	256	712	712	9,517	9,273	9,018	8,523
Oklahoma	680	730	746	645	40	118	120	120	0	0	0	0	720	848	866	765
Texas	7,090	6,718	6,345	5,973	1,451	1,451	1,095	1,073	256	256	712	712	8,797	8,425	8,152	7,758
Mountain:	3,537	3,687	3,821	3,821	1,098	1,139	1,208	1,236	1,384	1,475	1,520	1,515	6,020	6,301	6,549	6,574
Arizona	552	550	550	548	0	0	0	0	391	390	390	390	943	940	940	938
Colorado	900	940	940	940	45	50	60	60	700	710	720	720	1,645	1,700	1,720	1,720
Idaho	1,056	1,200	1,250	1,270	478	482	527	537	100	150	180	180	1,634	1,832	1,957	1,987
Montana	40	57	58	60	284	316	389	401	0	0	0	0	324	373	447	461
Nevada	170	170	170	170	34	34	34	34	0	0	0	0	204	204	204	204
New Mexico	634	585	653	633	43	43	43	45	143	175	180	172	820	803	876	850
Utah	60	60	70	70	164	164	80	80	0	0	0	0	224	224	150	150
Wyoming	125	125	130	130	50	50	75	79	50	50	50	53	225	225	255	264
Pacific:	4,561	4,912	4,687	4,771	1,725	1,845	2,078	2,363	0	0	200	200	6,286	6,757	6,965	7,334
California	4,073	4,388	4,065	4,065	380	410	410	410	0	0	200	200	4,453	4,798	4,675	4,675
Oregon	246	264	292	328	644	686	738	811	0	0	0	0	890	950	1,030	1,139
Washington	242	260	330	378	701	749	930	1,142	0	0	0	0	943	1,009	1,260	1,520
Alaska	3	1	1	1	4	1	1	1	0	0	0	0	7	2	2	2
Hawaii	70	80	80	80	6	6	6	6	0	0	0	0	76	86	86	86
Total	25,465	29,205	31,673	33,143	7,294	7,807	7,867	8,215	2,329	2,431	3,328	3,302	35,150	39,443	42,868	44,660

Appendix table 3—Acreage irrigated with onfarm pumped water, by type of distribution system and region and State¹

Region and State	Big gun				Center pivot				Other sprinkler				Surface			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres																
Northeast:	19	26	33	62	18	42	47	67	251	231	234	200	5	5	6	1
Connecticut	0	0	*	1	*	0	0	0	9	12	7	7	*	*	1	1
Delaware	7	11	16	16	9	14	21	21	10	5	5	5	0	0	0	0
Maine	0	0	0	0	*	0	0	0	32	7	7	7	*	*	*	*
Maryland	1	4	6	9	4	23	21	31	19	6	13	9	0	0	0	0
Massachusetts	0	0	0	0	*	0	0	0	6	32	32	32	0	*	*	*
New Hampshire	0	0	0	0	*	0	0	0	2	7	7	7	0	0	*	*
New Jersey	0	0	0	25	5	5	5	15	95	95	95	65	5	5	5	0
New York	8	8	8	8	0	0	0	0	50	46	47	47	0	0	0	0
Pennsylvania	3	3	3	3	0	0	0	0	16	16	16	16	0	0	0	0
Rhode Island	0	0	0	0	*	*	*	*	9	3	3	3	*	0	0	0
Vermont	0	0	0	0	*	*	*	*	3	2	2	2	0	0	0	0
Lake States:	50	178	322	361	209	440	618	706	127	121	200	185	27	12	14	17
Michigan	11	11	115	141	62	62	156	152	36	36	100	108	0	0	0	0
Minnesota	25	101	129	135	69	245	297	339	11	41	53	29	27	10	12	15
Wisconsin	14	66	78	85	78	133	165	215	80	44	47	48	0	2	2	2
Corn Belt:	48	84	139	156	70	234	420	485	65	78	91	61	188	237	277	288
Illinois	10	12	27	28	25	28	102	103	14	13	10	10	1	*	1	1
Indiana	3	16	13	27	12	23	38	70	11	12	27	14	7	7	7	5
Iowa	9	26	46	40	7	92	160	175	13	13	13	13	29	35	22	22
Missouri	21	26	49	54	21	85	114	131	5	4	5	8	151	195	247	259
Ohio	5	4	4	7	5	6	6	6	22	36	36	16	0	0	0	1
Northern Plains:	60	116	159	160	1,536	3,179	3,689	4,178	580	722	798	808	5,074	5,824	6,385	6,447
Kansas	45	13	52	52	450	807	988	987	45	65	75	75	1,765	2,274	2,474	2,473
Nebraska	0	63	69	70	1,025	2,137	2,357	2,815	468	566	624	635	3,263	3,520	3,881	3,946
North Dakota	3	13	11	11	26	75	118	137	2	3	5	4	24	6	5	4
South Dakota	12	27	27	27	35	160	226	239	65	88	94	94	22	24	25	24
Appalachia:	9	28	132	172	9	8	20	49	162	181	132	114	14	6	7	9
Kentucky	0	0	0	1	0	0	0	1	26	26	26	27	*	1	1	1
North Carolina	0	6	100	128	7	6	15	25	92	106	47	44	11	2	2	1
Tennessee	2	2	6	8	2	2	5	7	11	12	11	12	3	3	3	3
Virginia	7	19	26	35	0	0	0	16	30	36	48	31	*	0	0	3
West Virginia	0	1	0	0	0	0	0	0	3	1	0	0	*	0	1	1

See footnotes at end of table.

Continued—

Appendix table 3—Acreage irrigated with onfarm pumped water, by type of distribution system and region and State¹—Continued

Region and State	Big gun				Center pivot				Other sprinkler				Surface			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres																
Southeast:	322	686	916	872	64	168	615	770	488	554	533	1,015	1,166	1,303	1,409	1,201
Alabama	6	38	84	75	6	16	44	66	13	6	8	14	*	0	0	0
Florida	307	377	493	365	19	22	29	32	292	337	341	871	1,165	1,301	1,404	1,182
Georgia	0	257	308	386	39	129	510	618	154	191	168	103	0	0	0	12
South Carolina	9	14	31	46	0	1	32	54	29	20	16	27	1	2	5	7
Delta States:	19	26	68	51	25	29	168	270	60	44	108	143	2,583	2,564	2,692	3,294
Arkansas	14	23	53	24	17	20	53	70	48	34	70	102	1,617	1,623	1,649	2,204
Louisiana	3	3	15	16	3	6	86	100	7	6	19	17	659	546	625	627
Mississippi	2	0	0	11	5	3	29	100	5	4	19	26	307	395	418	463
Southern Plains:	108	99	104	107	522	713	780	698	1,767	1,705	1,669	1,507	7,121	6,762	6,466	6,212
Oklahoma	20	15	22	29	82	124	209	155	271	349	365	265	347	360	270	316
Texas	88	84	82	78	440	589	571	543	1,496	1,356	1,304	1,242	6,774	6,402	6,196	5,896
Mountain:	1	5	12	16	918	1,052	1,247	1,313	1,659	1,867	2,000	2,070	3,416	3,378	3,290	3,176
Arizona	0	0	0	0	28	28	28	30	38	28	28	28	877	884	884	879
Colorado	0	0	0	0	353	547	601	633	64	50	51	57	1,227	1,104	1,068	1,030
Idaho	0	0	0	2	180	210	225	224	1,209	1,400	1,530	1,581	224	220	200	181
Montana	1	5	11	12	23	36	60	66	54	79	113	116	240	252	264	267
Nevada	0	0	0	0	10	11	11	10	10	11	11	11	185	183	183	183
New Mexico	0	0	0	0	233	129	225	246	16	31	60	68	571	643	591	536
Utah	0	0	0	0	20	20	11	11	180	180	120	120	25	25	19	19
Wyoming	0	0	1	2	71	71	86	93	88	88	87	89	67	67	81	81
Pacific:	0	39	54	50	297	317	545	643	2,434	2,582	2,661	2,798	3,556	3,820	3,705	3,843
California	0	0	0	0	0	0	0	0	935	1,008	982	981	3,518	3,790	3,693	3,693
Oregon	0	29	38	46	98	105	156	233	792	817	833	860	0	0	3	0
Washington	0	10	16	4	198	212	389	410	707	757	846	957	38	30	9	150
Alaska	0	0	0	0	1	0	0	0	3	2	2	2	0	0	0	0
Hawaii	0	0	0	0	0	1	1	1	14	28	28	28	56	57	57	57
Total	636	1,296	1,939	2,007	3,669	6,184	8,151	9,180	7,627	8,145	8,486	8,901	23,262	24,025	24,365	24,545

* Less than 500 acres.

¹Includes only acres irrigated with pumped water.

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State¹

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres												
Northeast:	31	30	25	35	68	101	107	147	177	160	133	135
Connecticut	1	1	*	1	2	3	2	2	6	7	2	2
Delaware	3	4	3	3	8	18	31	31	12	7	8	8
Maine	1	0	0	0	2	2	2	2	4	5	5	5
Maryland	2	2	3	4	10	17	24	31	7	12	9	10
Massachusetts	4	4	4	4	0	0	0	0	25	24	24	24
New Hampshire	1	1	1	1	2	2	2	2	4	4	4	4
New Jersey	11	11	7	15	16	32	17	50	74	58	39	40
New York	6	5	5	5	23	22	24	24	29	27	26	26
Pennsylvania	2	2	2	2	3	3	3	3	13	13	13	13
Rhode Island	*	*	*	*	1	1	1	1	2	2	2	2
Vermont	*	*	*	*	1	1	1	1	1	1	1	1
Lake States:	295	452	595	705	81	237	424	432	23	49	106	114
Michigan	87	87	156	168	16	16	119	128	5	5	89	97
Minnesota	72	237	288	329	39	120	180	179	9	32	6	5
Wisconsin	136	128	151	208	26	101	125	125	9	12	11	12
Corn Belt:	72	155	286	315	75	256	429	460	114	95	59	54
Illinois	6	7	63	64	9	9	63	64	25	26	6	6
Indiana	3	17	40	52	5	16	26	39	13	14	14	19
Iowa	12	63	109	119	20	63	103	101	23	34	18	18
Missouri	40	52	58	71	36	161	230	247	40	3	3	2
Ohio	11	16	16	9	5	7	7	9	13	18	18	9
Northern Plains:	1,572	2,612	3,274	3,594	1,544	2,915	2,793	2,846	151	72	79	81
Kansas	170	503	788	787	139	535	460	460	22	0	0	0
Nebraska	1,308	1,886	2,149	2,448	1,360	2,263	2,218	2,260	118	63	69	74
North Dakota	42	80	122	132	9	14	13	23	3	2	3	0
South Dakota	52	143	215	227	36	103	102	103	8	7	7	7
Appalachia:	104	18	30	23	22	87	139	182	62	114	113	128
Kentucky	0	0	0	5	4	4	4	4	23	23	23	21
North Carolina	98	11	20	8	5	59	101	129	5	50	39	57
Tennessee	3	4	4	6	5	6	8	10	7	7	9	9
Virginia	3	3	6	4	7	18	26	39	25	33	41	40
West Virginia	*	*	*	*	1	*	*	*	2	1	1	1

See footnotes at end of table.

Continued—

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State¹—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres												
Southeast:	587	582	963	1,120	1,045	1,613	1,968	2,319	189	240	211	197
Alabama	4	6	15	25	10	38	114	118	10	10	5	5
Florida	542	534	615	684	954	1,233	1,290	1,499	96	75	102	108
Georgia	8	35	306	369	73	317	513	617	83	150	99	79
South Carolina	33	7	27	42	8	25	51	85	0	5	5	5
Delta States:	504	781	1,571	2,019	645	1,102	1,197	1,499	591	310	93	28
Arkansas	339	565	1,316	1,801	184	616	406	503	424	191	25	3
Louisiana	101	84	104	65	269	232	502	625	135	115	63	20
Mississippi	64	132	151	153	192	254	289	371	32	4	5	5
Southern Plains:	2,007	2,139	2,054	1,957	151	156	165	159	108	105	103	94
Oklahoma	102	142	140	133	49	59	73	71	20	22	21	16
Texas	1,905	1,997	1,914	1,824	102	97	92	88	88	83	82	78
Mountain:	4,296	4,619	4,789	4,872	308	350	333	380	86	75	138	63
Arizona	613	649	649	648	0	0	0	0	0	0	0	0
Colorado	1,100	1,138	1,136	1,163	100	100	50	100	20	20	101	21
Idaho	1,568	1,750	1,876	1,901	49	60	60	62	16	14	13	15
Montana	271	315	383	395	37	39	46	48	14	15	13	13
Nevada	159	163	163	159	41	41	41	41	2	0	0	2
New Mexico	204	223	232	245	47	76	108	100	31	23	8	10
Utah	190	190	131	130	16	16	8	10	0	0	0	0
Wyoming	191	191	219	231	18	18	20	19	3	3	3	2
Pacific:	6,197	6,717	6,745	7,118	4	9	134	130	0	0	0	0
California	4,364	4,758	4,462	4,460	4	9	128	130	0	0	0	0
Oregon	890	950	1,027	1,139	0	0	3	0	0	0	0	0
Washington	943	1,009	1,256	1,519	0	0	3	0	0	0	0	0
Alaska	3	2	2	2	*	0	0	0	1	*	*	0
Hawaii	72	85	85	85	0	0	0	0	1	0	0	0
Total	15,740	18,192	20,419	21,845	3,943	6,826	7,689	8,524	1,503	1,220	1,035	897

See footnotes at end of table.

Continued—

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State¹—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres								
Northeast:	0	0	41	0	18	13	13	13
Connecticut	0	0	0	0	*	*	3	3
Delaware	0	0	0	0	4	1	0	0
Maine	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	5	3	4	4
Massachusetts	0	0	0	0	4	4	4	4
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	0	0	41	0	5	5	2	2
New York	0	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	*	*	*	*
Rhode Island	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0
Lake States:	0	0	0	0	11	12	29	18
Michigan	0	0	0	0	0	0	7	8
Minnesota	0	0	0	0	11	8	17	5
Wisconsin	0	0	0	0	0	4	5	5
Corn Belt:	1	25	6	5	100	103	146	155
Illinois	0	0	3	3	11	11	4	4
Indiana	*	*	0	0	12	11	5	6
Iowa	0	1	0	0	3	5	11	12
Missouri	1	24	3	2	71	71	121	130
Ohio	0	0	0	0	3	5	5	3
Northern Plains:	2,430	3,231	3,593	3,638	1,552	1,008	1,291	1,433
Kansas	1,792	1,911	2,067	2,067	183	209	273	273
Nebraska	638	1,320	1,525	1,570	1,331	754	970	1,113
North Dakota	0	0	1	1	1	0	0	0
South Dakota	0	0	0	0	37	45	48	47
Appalachia:	*	2	2	3	3	1	6	7
Kentucky	0	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	3	3
Tennessee	*	2	2	3	1	*	2	2
Virginia	0	0	0	0	2	1	1	2
West Virginia	0	0	0	0	0	0	0	0

Continued—

See footnotes at end of table.

Appendix table 4—Acreage irrigated with onfarm pumped water, by type of energy and region and State¹—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 acres								
Southeast:	*	2	2	2	222	273	336	222
Alabama	*	2	2	2	1	4	5	5
Florida	0	0	0	0	192	194	261	161
Georgia	0	0	0	0	29	75	69	54
South Carolina	0	0	0	0	0	0	1	2
Delta States:	205	182	117	110	744	287	58	104
Arkansas	70	70	56	70	678	258	21	23
Louisiana	135	112	61	40	34	17	15	10
Mississippi	0	0	0	0	32	12	22	71
Southern Plains:	6,742	6,341	6,204	5,837	508	529	493	474
Oklahoma	435	473	498	413	113	153	134	132
Texas	6,307	5,868	5,706	5,424	395	376	359	342
Mountain:	1,156	1,109	1,089	1,075	184	138	198	183
Arizona	330	291	291	290	0	0	0	0
Colorado	330	332	332	335	100	100	101	101
Idaho	5	6	6	7	1	2	2	2
Montana	*	0	0	0	3	4	5	5
Nevada	0	0	0	0	2	0	0	2
New Mexico	484	473	452	435	54	8	75	60
Utah	0	0	0	0	18	18	11	9
Wyoming	7	7	8	8	6	6	4	4
Pacific:	85	31	85	85	0	0	0	0
California	85	31	85	85	0	0	0	0
Oregon	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0
Alaska	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0
Total	10,616	10,923	11,139	10,755	3,342	2,364	2,570	2,609

*Less than 500 acres.

¹Includes only acres irrigated with pumped water.

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
	Million kWh				1,000 gallons							
Ground water:												
Northeast:	5.3	4.9	3.8	6.7	848	2,042	2,151	3,746	4,362	3,005	2,041	2,509
Connecticut	*	*	*	*	0	9	5	5	18	29	7	7
Delaware	.6	1.1	.7	.8	193	565	874	874	363	266	296	296
Maine	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	.2	.4	1.0	1.5	105	356	707	1,080	99	306	249	244
Massachusetts	*	*	*	*	0	0	0	0	18	17	18	18
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0
New Jersey	3.9	2.8	1.4	3.7	285	843	281	1,440	3,417	1,933	1,055	1,518
New York	.6	.6	.7	.6	256	258	275	338	401	403	368	378
Pennsylvania	*	*	*	.1	9	9	9	9	48	48	48	48
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0	0	0
Lake States:	75.8	194.4	252.5	333.6	2,131	9,336	16,076	21,313	750	2,404	3,893	4,217
Michigan	18.3	18.4	43.4	46.7	339	340	3,279	4,374	141	141	3,077	3,294
Minnesota	20.5	100.0	118.8	134.3	1,107	4,934	7,358	8,848	323	1,646	249	171
Wisconsin	37.0	76.0	90.3	152.6	685	4,061	5,439	8,091	286	615	567	752
Corn Belt:	10.3	33.4	79.2	90.2	1,185	4,208	8,598	10,918	2,792	2,474	1,344	1,616
Illinois	2.0	1.7	21.1	22.1	301	199	2,086	2,086	1,024	653	107	107
Indiana	.9	7.2	13.8	17.8	133	711	683	1,240	477	574	475	882
Iowa	1.8	15.7	34.7	40.2	312	1,439	3,424	4,400	446	973	476	495
Missouri	4.4	7.2	8.0	9.4	388	1,788	2,336	3,096	673	44	58	36
Ohio	1.2	1.6	1.6	.8	51	68	69	96	171	228	229	96
Northern Plains:	905.0	1,444.0	1,674.0	1,940.1	92,922	183,784	170,756	179,598	5,573	5,121	5,636	6,015
Kansas	109.0	164.0	190.0	199.0	7,747	39,578	31,583	31,583	1,938	0	0	0
Nebraska	772.0	1,181.0	1,321.0	1,582.1	84,140	139,913	134,634	143,197	3,289	4,862	5,264	5,915
North Dakota	14.0	43.0	63.0	47.0	302	714	637	813	142	127	177	0
South Dakota	10.0	56.0	100.0	112.0	732	3,578	3,902	4,005	204	131	195	100
Appalachia:	1.7	2.5	4.7	5.2	83	318	370	633	208	331	401	204
Kentucky	0	0	0	0	2	2	3	3	16	14	14	14
North Carolina	1.3	1.7	3.7	2.7	7	98	75	235	9	21	0	48
Tennessee	.3	.5	.7	1.7	54	65	138	350	91	92	87	142
Virginia	.1	.3	.3	.7	20	151	154	45	92	202	300	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0

Continued—

See footnotes at end of table.

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
	-----1,000 MCF-----				-----1,000 gallons-----			
Ground water:								
Northeast:	0	0	242	0	546	370	172	164
Connecticut	0	0	0	0	4	1	12	12
Delaware	0	0	0	0	151	58	0	0
Maine	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	82	87	155	152
Massachusetts	0	0	0	0	4	3	0	0
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	0	0	242	0	305	219	0	0
New York	0	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	1	0	0	0
Rhode Island	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0
Lake States:	0	0	0	0	462	899	1,726	1,146
Michigan	0	0	0	0	0	0	321	340
Minnesota	0	0	0	0	462	514	933	216
Wisconsin	0	0	0	0	0	385	473	590
Corn Belt:	6	9	7	4.4	2,391	2,777	3,088	3,382
Illinois	0	0	0	0	549	347	0	0
Indiana	3	3	0	0	507	609	158	316
Iowa	0	0	0	0	70	182	595	660
Missouri	3	5	7	4.4	1,212	1,566	2,265	2,376
Ohio	0	0	0	0	54	71	72	30
Northern Plains:	25,551	36,745	38,756	39,827	112,776	98,113	123,358	142,325
Kansas	19,383	23,982	24,282	24,282	16,961	23,208	28,809	28,809
Nebraska	6,166	12,762	14,474	15,545	94,569	72,929	92,108	111,011
North Dakota	0	0	0	0	59	0	0	0
South Dakota	0	0	0	0	1,187	1,974	2,441	2,505
Appalachia:	1	2	5	8.9	24	37	54	89
Kentucky	0	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	0	0
Tennessee	1	2	5	8.9	14	20	54	89
Virginia	0	0	0	0	10	16	0	0
West Virginia	0	0	0	0	0	0	0	0

See footnotes at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
	Million kWh				1,000 gallons							
Ground water:												
Southeast:	120.1	176.5	452.3	503.8	12,666	38,689	71,005	108,084	6,029	13,258	15,103	12,474
Alabama	.3	1.8	4.1	7.4	74	791	1,328	2,100	93	280	0	61
Florida	111.6	155.5	209.5	237.6	11,015	23,010	31,022	52,140	3,937	4,477	6,037	5,917
Georgia	1.5	15.8	227.6	247.8	1,412	14,373	37,683	51,282	1,999	8,500	9,066	6,496
South Carolina	6.7	3.4	11.1	11.0	164	514	973	2,562	0	0	0	0
Delta States:	103.2	179.8	620.6	795.1	14,066	23,172	34,459	54,924	14,482	7,866	3,028	856
Arkansas	64.1	137.0	555.5	729.7	3,167	13,531	14,613	24,990	9,905	4,836	914	0
Louisiana	21.0	17.8	27.9	18.7	5,527	4,929	13,012	16,134	3,457	2,936	1,973	651
Mississippi	18.1	25.0	37.5	46.7	5,372	4,712	6,834	13,800	1,120	93	140	205
Southern Plains:	1,146.0	1,232.0	1,371.0	1,242.0	8,783	7,979	9,506	8,516	8,759	8,084	8,678	7,554
Oklahoma	90.0	130.0	147.0	120.0	3,563	3,034	4,281	3,470	2,229	1,898	2,142	1,240
Texas	1,056.0	1,102.0	1,224.0	1,122.0	5,220	4,945	5,224	5,046	6,530	6,186	6,536	6,314
Mountain:	5,766.0	7,060.0	7,601.0	7,907.0	32,810	33,842	40,449	40,732	12,962	9,072	6,117	6,942
Arizona	1,736.0	2,639.0	2,802.0	2,963.0	0	0	0	0	0	0	0	0
Colorado	331.0	343.0	412.0	475.0	4,243	4,243	4,062	4,243	300	300	303	303
Idaho	2,750.0	3,282.0	3,555.0	3,586.0	8,262	10,028	10,184	11,205	3,414	3,136	2,866	3,463
Montana	28.0	62.0	64.0	64.0	591	1,061	1,089	1,094	687	919	943	855
Nevada	310.0	166.0	166.0	174.0	7,862	4,122	4,122	4,122	492	0	0	0
New Mexico	332.0	289.0	327.0	359.0	9,383	11,922	18,279	17,492	7,825	4,474	1,759	2,187
Utah	112.0	112.0	108.0	113.0	908	908	744	744	0	0	0	0
Wyoming	167.0	167.0	167.0	173.0	1,561	1,558	1,969	1,832	244	243	246	134
Pacific:	4,656.0	5,012.0	5,186.0	5,650.0	0	0	17,645	15,712	0	0	0	0
California	3,432.0	3,706.0	3,594.0	3,762.0	0	0	15,712	15,712	0	0	0	0
Oregon	265.0	285.0	316.0	350.0	0	0	731	0	0	0	0	0
Washington	959.0	1,021.0	1,276.0	1,538.0	0	0	1,202	0	0	0	0	0
Alaska	.3	.1	.1	1.0	2	0	0	0	12	3	3	3
Hawaii	580.1	691.6	691.6	691.6	0	0	0	0	723	0	0	0
Total ground water	13,369.8	16,031.2	17,936.8	19,165.4	165,496	304,022	371,013	444,173	56,653	51,622	46,238	42,387

Continued—

See footnotes at end of table.

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
	-----1,000 MCF-----				-----1,000 gallons-----			
Ground water:								
Southeast:	1	0	0	0	10,723	19,911	27,541	17,084
Alabama	1	0	0	0	9	206	205	228
Florida	0	0	0	0	9,843	14,392	19,404	12,236
Georgia	0	0	0	0	872	5,312	7,932	4,620
South Carolina	0	0	0	0	0	0	0	0
Delta States:	680	669	651	679	22,289	9,969	2,635	5,227
Arkansas	248	302	343	448	19,808	9,068	1,143	1,472
Louisiana	432	367	308	231	1,080	550	617	389
Mississippi	0	0	0	0	1,400	350	876	3,366
Southern Plains:	66,344	67,323	67,525	62,895	43,792	51,559	47,405	43,858
Oklahoma	5,943	7,473	8,703	6,201	11,143	16,608	14,728	12,403
Texas	60,401	59,850	58,822	56,694	32,649	34,951	32,677	31,455
Mountain:	31,888	32,173	33,590	35,087	22,261	23,360	24,474	20,942
Arizona	14,432	18,304	19,435	20,457	0	0	0	0
Colorado	2,050	2,072	2,072	2,222	1,842	1,842	1,864	1,864
Idaho	116	117	118	159	387	390	392	397
Montana	7	0	0	0	66	255	262	213
Nevada	0	0	0	0	615	0	0	0
New Mexico	15,161	11,559	11,873	12,165	17,117	18,640	19,789	16,412
Utah	0	0	0	0	1,624	1,624	1,551	1,551
Wyoming	122	121	92	84	610	609	616	505
Pacific:	1,000	1,136	1,638	1,638	0	0	0	0
California	1,000	1,136	1,638	1,638	0	0	0	0
Oregon	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0
Alaska	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0
Total ground water	125,471	139,060	142,412	140,139	215,264	206,998	230,451	234,217

See footnotes at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
	-----Million kWh-----				-----1,000 gallons-----							
Surface water:												
Northeast:	3.1	2.5	2.3	3.9	718	947	1,125	2,013	2,259	1,964	1,865	1,800
Connecticut	.1	.1	*	.1	34	37	26	26	85	110	39	39
Delaware	.2	.1	.1	.1	52	74	164	164	97	39	49	49
Maine	.1	0	0	0	29	13	14	14	72	40	40	40
Maryland	.4	.4	.4	.4	182	374	452	702	170	321	288	330
Massachusetts	.5	.5	.5	.6	0	0	0	0	395	382	383	383
New Hampshire	.1	.1	.1	.1	26	28	29	29	64	76	76	76
New Jersey	.9	.6	.6	1.8	128	180	181	774	749	414	414	308
New York	.5	.4	.3	.4	195	164	186	231	306	257	254	252
Pennsylvania	.3	.3	.3	.4	51	51	51	51	268	267	267	267
Rhode Island	*	*	*	*	13	13	13	13	32	33	34	34
Vermont	*	*	*	*	9	8	9	9	21	21	22	22
Lake States:	34.8	25.3	33.9	39.0	828	2,451	3,973	5,481	310	493	1,710	1,978
Michigan	13.1	13.2	19.8	22.6	243	243	1,487	2,068	101	101	1,396	1,620
Minnesota	5.1	8.0	10.0	11.5	277	424	604	525	81	154	67	50
Wisconsin	16.6	4.1	4.1	5.0	307	1,783	1,881	2,888	128	237	248	308
Corn Belt:	2.9	6.3	8.1	11.5	247	1,678	2,199	3,303	621	1,044	1,005	877
Illinois	*	.2	.4	.4	0	50	36	36	0	227	171	171
Indiana	.4	2.7	2.5	5.4	61	219	298	760	219	411	201	205
Iowa	.2	.7	2.7	3.0	44	157	35	52	63	113	341	371
Missouri	.8	.6	.4	1.5	78	1,163	1,742	2,325	128	0	0	0
Ohio	1.5	2.1	2.1	1.2	63	87	88	130	212	292	293	130
Northern Plains:	38.0	110.0	128.0	133.0	2,092	12,063	11,042	11,491	1,637	810	708	1,029
Kansas	1.0	2.0	2.0	2.0	274	1,440	1,557	1,557	0	0	0	215
Nebraska	9.0	54.0	54.0	54.0	0	6,451	5,499	5,515	1,126	224	215	197
North Dakota	2.0	3.0	4.0	3.0	32	71	42	59	15	0	0	0
South Dakota	26.0	51.0	68.0	74.0	1,786	4,100	3,945	4,360	497	586	494	617
Appalachia:	17.3	2.4	5.2	2.4	336	1,819	4,014	6,918	1,173	3,172	3,784	4,937
Kentucky	0	0	0	0	45	43	44	44	317	309	310	310
North Carolina	16.4	1.1	2.6	.3	90	1,078	2,953	4,625	113	1,214	1,455	2,128
Tennessee	.4	.5	.5	1.2	66	75	96	235	111	118	204	336
Virginia	.5	.8	2.1	.9	122	612	921	2,014	578	1,485	1,811	2,160
West Virginia	*	*	*	*	12	8	0	0	54	43	3	3

Continued—

See footnotes at end of table.

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
	-----1,000 MCF-----				-----1,000 gallons-----			
Surface water:								
Northeast:	0	0	0	0	333	253	342	292
Connecticut	0	0	0	0	0	4	65	65
Delaware	0	0	0	0	40	9	0	0
Maine	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	142	103	142	138
Massachusetts	0	0	0	0	79	84	84	84
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	67	47	47	0
New York	0	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	5	4	5	5
Rhode Island	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0
Lake States:	0	0	0	0	115	42	340	230
Michigan	0	0	0	0	0	0	145	168
Minnesota	0	0	0	0	115	42	194	62
Wisconsin	0	0	0	0	0	0	0	0
Corn Belt:	0	115	16	16	553	641	1,196	1,269
Illinois	0	0	16	16	0	121	221	221
Indiana	0	0	0	0	246	428	96	102
Iowa	0	3	0	0	10	0	0	0
Missouri	0	112	0	0	230	0	788	880
Ohio	0	0	0	0	66	91	91	66
Northern Plains:	0	588	591	1,216	9,898	7,971	8,966	11,055
Kansas	0	0	0	608	428	1,310	1,709	3,762
Nebraska	0	588	591	603	6,567	3,362	3,762	3,820
North Dakota	0	0	0	5	6	0	0	0
South Dakota	0	0	0	0	2,896	3,297	3,495	3,473
Appalachia:	0	3	4	12	98	59	261	340
Kentucky	0	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	139	144
Tennessee	0	3	4	12	35	0	39	60
Virginia	0	0	0	0	64	59	82	136
West Virginia	0	0	0	0	0	0	0	0

See footnotes at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
	----- Million kWh -----				----- 1,000 gallons -----							
Surface water:												
Southeast:	24.6	40.7	88.3	134.0	6,205	25,593	22,029	41,472	1,384	9,514	3,072	2,451
Alabama	.4	.7	1.9	4.5	102	677	3,251	4,482	128	215	236	275
Florida	17.1	22.5	18.6	61.9	5,064	7,862	6,512	23,310	0	0	0	342
Georgia	1.0	16.8	62.9	58.6	888	16,212	10,393	11,315	1,257	8,996	2,500	1,554
South Carolina	6.1	.7	4.9	9.0	151	841	1,874	2,365	0	302	335	280
Delta States:	12.4	17.7	12.5	16.7	2,146	3,407	5,554	6,789	1,837	1,527	806	289
Arkansas	6.3	11.3	.3	7.0	467	1,896	533	234	974	960	89	57
Louisiana	4.6	3.2	8.9	5.6	1,230	865	4,309	5,385	770	554	703	232
Mississippi	1.5	3.2	3.3	4.1	448	645	712	1,170	94	12	14	0
Southern Plains:	116.0	139.0	103.0	98.0	1,122	2,535	2,746	2,985	477	1,010	810	870
Oklahoma	0	11.0	8.0	3.0	360	1,769	2,178	2,431	0	531	454	507
Texas	116.0	128.0	95.0	95.0	762	766	569	554	477	479	356	363
Mountain:	735.0	781.0	836.0	883.0	4,479	5,308	5,348	5,406	1,141	1,166	1,177	1,248
Arizona	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	2.0	2.0	4.0	3.0	0	0	0	0	0	0	10	6
Idaho	451.0	456.0	496.0	518.0	1,524	1,965	1,965	1,801	595	491	491	501
Montana	118.0	153.0	231.0	252.0	1,513	1,751	2,622	2,857	516	657	656	714
Nevada	8.0	14.0	14.0	14.0	197	347	347	347	12	0	0	0
New Mexico	4.0	4.0	11.0	12.0	0	0	0	0	0	0	0	0
Utah	146.0	146.0	65.0	68.0	1,189	1,189	365	365	0	0	0	0
Wyoming	6.0	6.0	15.0	16.0	56	56	49	36	18	18	20	27
Pacific:	1,803.0	1,921.0	2,260.0	2,946.0	69	198	0	0	0	0	0	0
California	222.0	239.0	239.0	239.0	69	198	0	0	0	0	0	0
Oregon	445.0	473.0	510.0	886.0	0	0	0	0	0	0	0	0
Washington	1,136.0	1,209.0	1,511.0	1,821.0	0	0	0	0	0	0	0	0
Alaska	*	*	*	*	0	0	0	0	3	2	2	2
Hawaii	.2	1.6	1.6	1.6	0	0	0	0	0	0	0	0
Total surface water	2,787.3	3,047.2	3,478.9	4,269.1	18,242	56,699	58,030	85,858	10,843	20,702	15,010	15,479
Total ground water and surface water	16,157.1	19,078.4	21,415.7	23,434.5	183,738	360,721	429,043	530,031	67,496	72,324	61,248	57,866

See footnotes at end of table.

Continued—

Appendix table 5—Quantity of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
	-----1,000 MCF-----				-----1,000 gallons-----			
Surface water:								
Southeast:	0	11	12	14	568	5,654	2,390	2,231
Alabama	0	11	12	14	20	31	118	138
Florida	0	0	0	0	0	0	0	0
Georgia	0	0	0	0	548	5,622	2,188	1,953
South Carolina	0	0	0	0	0	0	84	140
Delta States:	96	66	64	27	2,305	1,276	319	428
Arkansas	0	0	6	0	1,947	1,130	56	0
Louisiana	96	66	59	27	241	99	195	138
Mississippi	0	0	0	0	117	47	69	290
South Plains:	3,574	3,535	2,659	2,660	6,420	8,952	7,993	8,590
Oklahoma	0	121	125	137	2,251	4,759	4,882	5,492
Texas	3,574	3,414	2,534	2,523	4,169	4,193	3,111	3,098
Mountain:	33	49	56	70	2,411	2,602	1,394	1,443
Arizona	0	0	0	0	0	0	0	0
Colorado	0	0	0	0	0	0	12	8
Idaho	29	46	46	47	0	148	148	156
Montana	0	0	0	0	215	273	410	446
Nevada	0	0	0	0	15	0	0	0
New Mexico	4	3	9	13	0	0	0	0
Utah	0	0	0	0	2,126	2,126	799	799
Wyoming	0	0	10	10	55	55	25	34
Pacific:	0	0	0	0	0	0	0	0
California	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0
Alaska	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0
Total surface water	3,673	4,323	3,399	3,407	22,709	27,450	23,201	23,178
Total ground water and surface water	129,144	143,383	145,811	143,546	237,973	234,448	253,652	257,395

* Less than 50,000 kWh.

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars												
Ground water:												
Northeast:	143	206	242	564	463	1,023	2,310	4,189	2,150	1,583	2,425	3,061
Connecticut	1	1	1	1	0	5	5	6	9	17	9	9
Delaware	17	45	44	62	73	276	953	1,014	178	125	358	361
Maine	0	0	0	0	0	0	0	0	0	0	0	0
Maryland	7	17	60	103	40	174	770	1,112	48	168	301	287
Massachusetts	1	1	2	2	0	0	0	0	9	9	21	22
New Hampshire	0	0	0	0	0	0	0	0	0	0	0	0
New Jersey	99	114	87	349	246	430	284	1,670	1,674	1,025	1,245	1,852
New York	16	26	44	43	100	131	289	378	208	214	435	473
Pennsylvania	2	2	4	4	3	4	9	9	23	26	56	57
Rhode Island	0	0	0	0	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0	0	0	0	0
Lake States:	1,687	6,806	16,357	24,115	771	4,211	16,408	21,435	364	1,221	4,592	5,033
Michigan	421	643	2,616	3,272	122	163	3,246	4,592	72	71	3,600	3,887
Minnesota	452	3,500	8,322	9,398	410	2,220	7,505	8,671	155	823	306	214
Wisconsin	814	2,663	5,419	11,445	240	1,827	5,656	8,172	137	326	686	932
Corn Belt:	229	1,092	4,121	5,931	438	1,868	8,080	10,893	1,335	1,288	1,596	2,001
Illinois	45	50	1,263	1,548	117	90	2,169	2,211	492	340	133	134
Indiana	21	288	830	1,247	51	355	676	1,252	239	287	560	1,084
Iowa	40	473	1,561	2,613	112	604	3,253	4,268	210	526	571	623
Missouri	96	217	365	468	140	786	1,915	3,065	310	21	64	42
Ohio	27	64	97	55	18	31	67	97	86	114	268	118
Northern Plains:	18,100	62,800	83,400	124,400	31,857	81,839	168,992	174,200	2,687	2,614	6,697	7,600
Kansas	2,200	5,800	10,300	12,900	2,866	17,018	30,951	30,600	911	0	0	0
Nebraska	15,400	53,100	66,100	102,800	28,608	62,961	133,288	138,900	1,612	2,480	6,264	7,500
North Dakota	300	1,600	2,400	3,100	112	321	656	800	68	70	213	0
South Dakota	200	2,300	4,600	5,600	271	1,538	4,097	3,900	95	65	221	100
Appalachia:	39	99	229	342	33	153	380	631	101	167	462	239
Kentucky	0	0	0	0	1	1	3	3	7	7	17	16
North Carolina	28	75	185	199	3	46	77	251	4	10	0	57
Tennessee	9	12	29	87	22	32	141	329	44	48	100	166
Virginia	2	12	15	56	7	72	159	48	45	101	345	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars								
Ground water:								
Northeast:	0	0	604	0	204	148	134	149
Connecticut	0	0	0	0	1	0	9	15
Delaware	0	0	0	0	48	23	0	15
Maine	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	28	34	121	134
Massachusetts	0	0	0	0	1	1	3	0
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	0	0	604	0	125	87	0	0
New York	0	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	0	0	0	0
Rhode Island	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0
Lake States:	0	0	0	0	143	359	1,053	937
Michigan	0	0	0	0	0	0	196	937
Minnesota	0	0	0	0	143	205	569	175
Wisconsin	0	0	0	0	0	153	288	490
Corn Belt:	4	12	13	10	722	1,058	1,733	2,479
Illinois	0	0	0	0	165	104	0	0
Indiana	2	0	0	0	157	243	95	246
Iowa	0	0	0	0	20	54	351	475
Missouri	3	6	13	10	364	626	1,238	1,734
Ohio	0	0	0	0	16	28	49	24
Northern Plains:	19,163	34,501	96,890	148,500	30,306	29,631	67,969	95,000
Kansas	14,538	19,185	60,705	101,900	4,410	6,962	15,845	19,900
Nebraska	4,626	15,315	36,185	46,600	25,534	21,878	50,660	73,300
North Dakota	0	0	0	0	18	0	0	0
South Dakota	0	0	0	0	334	789	1,464	1,800
Appalachia:	1	1	14	45	8	156	36	78
Kentucky	0	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	0	0
Tennessee	1	1	14	45	5	149	36	78
Virginia	0	0	0	0	4	6	0	0
West Virginia	0	0	0	0	0	0	0	0

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars												
Ground water:												
Southeast:	2,642	8,668	24,651	33,166	4,710	16,583	75,770	108,162	2,792	6,325	17,067	14,529
Alabama	6	60	250	554	29	356	1,301	2,016	42	140	0	71
Florida	2,456	7,772	12,575	19,011	4,076	9,204	33,504	54,226	1,851	2,105	6,641	6,923
Georgia	33	715	11,382	12,885	537	6,755	39,944	49,230	900	4,080	10,426	7,535
South Carolina	147	121	444	716	69	267	1,021	2,690	0	0	0	0
Delta States:	2,273	7,284	29,012	56,543	5,076	10,610	33,469	53,924	6,684	4,329	3,500	1,005
Arkansas	1,412	5,484	25,544	51,076	1,045	6,224	13,590	23,990	4,556	2,757	1,060	0
Louisiana	462	499	1,119	1,496	1,990	2,218	12,362	16,134	1,590	1,527	2,269	762
Mississippi	399	1,301	2,349	3,971	2,041	2,167	7,517	13,800	538	45	171	243
Southern Plains:	25,200	37,000	59,000	81,300	3,022	3,880	9,593	8,200	3,811	4,889	9,958	8,500
Oklahoma	2,000	3,900	6,600	8,400	1,247	1,365	4,369	3,500	1,003	1,044	2,507	1,400
Texas	23,200	33,100	52,400	72,900	1,775	2,514	5,224	4,700	2,808	3,845	7,451	7,100
Mountain:	103,100	165,500	289,300	331,600	12,255	14,036	40,306	40,100	6,109	4,527	7,164	8,500
Arizona	34,700	55,500	126,100	133,300	0	0	0	0	0	0	0	0
Colorado	7,300	11,900	20,700	35,600	1,500	1,900	4,100	4,000	138	154	351	400
Idaho	44,000	65,600	106,600	107,600	3,100	4,100	9,900	10,700	1,600	1,600	3,400	4,200
Montana	500	10,100	2,500	3,200	207	424	1,110	1,100	330	414	1,150	1,100
Nevada	4,600	5,000	8,300	10,800	3,145	1,854	4,369	4,300	246	0	0	0
New Mexico	6,600	8,700	16,300	27,300	3,378	4,649	18,096	17,400	3,678	2,237	1,970	2,600
Utah	1,700	2,800	3,700	5,100	363	408	722	800	0	0	0	0
Wyoming	3,700	5,900	5,100	8,700	562	701	2,009	1,800	117	122	293	200
Pacific:	79,700	170,400	243,100	287,900	127	0	17,116	15,200	0	0	0	0
California	68,600	155,300	215,800	233,200	0	0	15,241	15,200	0	0	0	0
Oregon	3,500	3,900	9,500	14,700	127	0	709	0	0	0	0	0
Washington	7,600	11,200	17,800	40,000	0	0	1,166	0	0	0	0	0
Alaska	10	3	8	8	1	0	0	0	7	2	0	0
Hawaii	18,564	34,580	51,872	51,872	0	0	0	0	433	0	0	0
Total ground water	251,687	494,438	801,292	997,741	58,753	134,206	372,723	436,904	26,472	26,942	53,462	50,468

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars								
Ground water:								
Southeast:	1	0	0	0	3,744	4,379	20,339	15,798
Alabama	1	0	0	0	3	61	127	180
Florida	0	0	0	0	3,445	4,317	15,135	10,767
Georgia	0	0	0	0	296	0	5,077	4,851
South Carolina	0	0	0	0	0	0	0	0
Delta States:	510	801	2,090	2,850	7,125	4,072	1,633	4,351
Arkansas	186	544	857	1,882	6,339	3,627	685	1,163
Louisiana	324	256	1,233	970	324	275	413	327
Mississippi	0	0	0	0	462	140	534	2,861
Southern Plains:	49,758	86,768	168,810	220,100	12,588	20,643	29,620	41,200
Oklahoma	4,457	8,968	21,758	21,700	3,120	6,643	10,015	9,700
Texas	45,301	77,800	147,052	198,400	9,468	14,500	19,605	31,500
Mountain:	24,492	50,909	84,046	157,300	6,329	9,505	16,650	16,200
Arizona	10,824	27,456	48,587	108,400	0	0	0	0
Colorado	2,100	2,300	5,100	9,300	534	718	1,010	1,300
Idaho	100	200	400	700	100	200	300	300
Montana	5	0	0	0	20	76	157	200
Nevada	0	0	0	0	197	0	0	0
New Mexico	11,371	20,807	29,682	38,600	4,793	7,600	13,654	12,700
Utah	0	0	0	0	520	649	1,086	1,300
Wyoming	92	146	277	300	165	262	443	400
Pacific:	750	1,704	7,158	9,700	0	0	0	0
California	750	1,704	7,158	9,700	0	0	0	0
Oregon	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0
Alaska	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0
Total ground water	94,678	174,698	359,625	538,505	62,203	69,905	139,167	176,192

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars												
Surface water:												
Northeast:	86	118	165	320	280	474	1,194	2,227	1,127	1,044	2,221	2,184
Connecticut	3	5	3	5	13	18	27	30	43	58	47	48
Delaware	4	5	8	11	20	36	179	190	47	18	59	60
Maine	3	0	0	0	11	6	14	16	37	20	48	49
Maryland	12	15	31	31	69	183	493	723	83	176	349	389
Massachusetts	15	31	34	47	0	0	0	0	202	202	459	467
New Hampshire	3	5	6	8	10	15	30	34	33	41	91	93
New Jersey	22	24	37	167	54	92	182	898	367	219	489	375
New York	13	16	21	24	76	83	196	258	159	136	300	315
Pennsylvania	9	14	20	21	19	26	50	53	129	141	312	320
Rhode Island	1	2	3	4	5	6	14	15	16	17	40	41
Vermont	1	1	2	2	3	4	9	10	11	10	26	27
Lake States:	802	883	2,133	2,755	298	1,110	4,045	5,603	152	254	2,015	2,361
Michigan	302	460	1,187	1,579	88	116	1,473	2,171	52	50	1,633	1,912
Minnesota	118	281	705	802	102	191	616	515	39	77	82	63
Wisconsin	382	142	241	374	108	802	1,957	2,917	62	126	300	386
Corn Belt:	69	238	443	763	90	750	2,106	3,288	304	531	1,202	1,094
Illinois	0	8	22	27	0	22	38	38	0	118	214	215
Indiana	10	111	150	381	23	109	295	767	109	205	237	252
Iowa	6	20	124	196	16	66	33	50	29	61	409	467
Missouri	19	17	23	76	28	511	1,655	2,302	59	0	0	0
Ohio	34	82	124	83	23	40	85	131	106	146	342	160
Northern Plains:	760	4,600	5,900	7,500	774	5,317	10,918	11,159	792	401	858	1,000
Kansas	20	100	100	100	101	619	1,526	1,500	0	0	0	200
Nebraska	200	2,400	2,700	3,500	0	2,903	5,444	5,300	552	114	256	200
North Dakota	40	100	100	200	12	32	43	59	7	0	0	0
South Dakota	500	2,000	3,000	3,700	661	1,763	3,905	4,300	233	287	602	600
Appalachia:	402	99	251	150	127	862	4,130	7,346	571	1,562	4,378	5,904
Kentucky	0	0	0	0	17	20	42	42	152	154	369	362
North Carolina	378	49	136	22	33	507	3,041	4,949	55	583	1,688	2,532
Tennessee	10	13	19	58	27	37	98	220	53	61	235	393
Virginia	13	34	96	66	45	294	949	2,135	283	742	2,083	2,613
West Virginia	1	3	0	4	4	3	0	0	27	19	4	4

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars								
Surface water:								
Northeast:	0	0	0	0	119	117	259	291
Connecticut	0	0	0	0	0	2	50	73
Delaware	0	0	0	0	13	4	0	0
Maine	0	0	0	0	0	0	0	0
Maryland	0	0	0	0	48	49	110	121
Massachusetts	0	0	0	0	28	37	66	94
New Hampshire	0	0	0	0	0	0	0	0
New Jersey	0	0	0	0	27	21	30	0
New York	0	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	2	2	3	4
Rhode Island	0	0	0	0	0	0	0	0
Vermont	0	0	0	0	0	0	0	0
Lake States:	0	0	0	0	36	18	207	184
Michigan	0	0	0	0	0	0	89	134
Minnesota	0	0	0	0	36	18	119	50
Wisconsin	0	0	0	0	0	0	0	0
Corn Belt:	0	5	41	80	168	258	645	936
Illinois	0	0	41	80	0	46	139	179
Indiana	0	0	0	0	76	175	57	80
Iowa	0	5	0	0	3	0	0	0
Missouri	0	0	0	0	69	0	385	624
Ohio	0	0	0	0	19	36	62	53
Northern Plains:	0	706	1,491	1,815	2,910	2,948	5,108	7,600
Kansas	0	0	0	0	246	419	940	2,600
Nebraska	0	706	1,476	1,800	1,773	1,176	2,069	2,500
North Dakota	0	0	15	15	52	0	0	0
South Dakota	0	0	0	0	839	1,352	2,097	2,500
Appalachia:	0	0	10	60	34	25	171	277
Kentucky	0	0	0	0	0	0	0	0
North Carolina	0	0	0	0	0	0	92	111
Tennessee	0	0	10	60	12	0	26	53
Virginia	0	0	0	0	22	25	53	113
West Virginia	0	0	0	0	0	0	0	0

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Electricity				Diesel				Gasoline			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars												
Surface water:												
Southeast:	565	1,683	4,566	8,921	2,315	11,493	23,204	41,890	623	5,219	3,159	2,863
Alabama	10	25	115	336	39	305	3,186	4,303	57	107	284	322
Florida	393	1,123	1,117	4,953	1,874	3,145	7,033	24,242	0	0	0	400
Georgia	22	503	3,139	3,047	337	7,606	11,016	10,862	566	4,948	2,875	1,802
South Carolina	140	32	195	585	63	437	1,968	2,483	0	163	0	339
Delta States:	290	715	588	1,285	767	1,559	5,373	6,780	847	841	928	338
Arkansas	145	457	16	190	154	872	495	225	448	547	103	67
Louisiana	110	89	355	448	443	389	4,094	5,385	354	288	809	271
Mississippi	35	169	217	347	170	297	783	1,170	45	6	17	0
Southern Plains:	2,700	4,100	4,600	6,400	385	1,141	2,790	2,900	205	555	937	800
Oklahoma	0	300	400	200	126	796	2,222	2,400	0	292	531	500
Texas	2,700	3,800	4,200	6,200	259	344	569	500	205	263	405	300
Mountain:	11,546	13,900	27,700	33,200	1,683	2,191	5,296	5,200	460	560	1,311	1,310
Arizona	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	46	100	200	200	0	0	0	0	1	2	11	10
Idaho	7,200	7,300	14,900	15,500	600	800	1,900	1,700	205	263	500	600
Montana	1,900	2,400	9,200	12,600	529	700	2,674	2,800	248	295	800	700
Nevada	100	400	700	900	79	156	368	400	6	0	0	0
New Mexico	100	100	500	900	0	0	0	0	0	0	0	0
Utah	2,200	3,600	2,200	3,100	475	535	354	300	0	0	0	0
Wyoming	100	800	400	800	20	102	50	36	8	35	24	30
Pacific:	19,300	29,900	78,400	92,500	26	449	0	0	0	0	0	0
California	4,400	10,000	9,100	8,000	26	449	0	0	0	0	0	0
Oregon	5,800	6,600	24,000	37,200	0	0	0	0	0	0	0	0
Washington	9,100	13,300	45,300	47,300	0	0	0	0	0	0	0	0
Alaska	2	3	5	5	0	0	0	0	2	1	0	0
Hawaii	6	85	128	128	0	0	0	0	0	0	0	0
Total surface water	36,528	56,324	124,879	153,927	6,755	25,346	59,055	86,393	5,102	10,973	17,008	17,854
Total ground water and surface water	288,215	550,762	926,171	1,151,668	65,508	159,552	431,778	523,297	31,574	37,915	70,470	68,322

Continued—

Appendix table 6—Total cost of energy used for onfarm pumped irrigation water, by region and State—Continued

Region and State	Natural gas				Liquefied petroleum gas			
	1974	1977	1980	1983	1974	1977	1980	1983
1,000 dollars								
Surface water:								
Southeast:	0	16	30	69	193	2,373	1,529	2,282
Alabama	0	16	30	69	7	12	73	109
Florida	0	0	0	0	0	0	0	0
Georgia	0	0	0	0	186	2,361	1,400	2,050
South Carolina	0	0	0	0	0	0	55	123
Delta States:	72	49	248	113	734	576	206	367
Arkansas	0	0	14	0	623	508	33	0
Louisiana	72	49	234	113	72	49	131	120
Mississippi	0	0	0	0	39	18	42	247
Southern Plains:	2,680	4,585	6,646	9,300	1,839	3,939	5,186	6,600
Oklahoma	0	146	312	500	630	2,094	3,319	4,200
Texas	2,680	4,439	6,334	8,800	1,209	1,845	1,867	2,400
Mountain:	3	5	52	285	123	967	830	933
Arizona	0	0	0	0	0	0	0	0
Colorado	0	0	7	0	0	0	7	7
Idaho	0	0	0	200	39	0	0	100
Montana	0	0	0	0	65	0	246	300
Nevada	0	0	0	0	4	0	0	0
New Mexico	0	5	22	45	0	0	0	0
Utah	0	0	0	0	0	871	559	500
Wyoming	0	0	30	40	15	95	18	26
Pacific:	0	0	0	0	0	0	0	0
California	0	0	0	0	0	0	0	0
Oregon	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0
Alaska	0	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0
Total surface water	2,755	5,503	8,518	11,719	5,972	11,332	14,140	19,470
Total ground water and surface water	97,433	80,201	368,143	550,224	68,175	81,237	153,370	195,662

Appendix table 7—Prices used for energy cost calculations, by region and State

Region and State	Electricity per kWh				Diesel per gallon				Gasoline per gallon				Natural Gas per MCF ¹				Liquefied petroleum gas per gallon			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
Dollars																				
Northeast:																				
Connecticut	.025	.040	.061	.082	.39	.51	1.04	1.16	.51	.53	1.20	1.22	0	0	0	0	.36	.45	.78	1.12
Delaware	.025	.040	.061	.083	.38	.49	1.09	1.16	.49	.47	1.20	1.22	0	0	0	0	.32	.45	.78	1.12
Maine	.025	.040	0	.068	.39	.50	0	1.16	.51	.50	0	1.22	0	0	0	0	.36	0	0	1.12
Maryland	.025	.040	.060	.070	.38	.49	1.09	1.03	.49	.55	1.21	1.18	0	0	0	0	.34	.48	.78	.88
Massachusetts	.025	.040	.061	.082	.39	.51	1.04	1.16	.51	.53	1.20	1.22	0	0	0	0	.36	.45	.78	1.12
New Hampshire	.025	.050	0	.080	.39	.52	0	1.16	.51	.55	0	1.22	0	0	0	0	.36	0	0	1.12
New Jersey	.025	.040	.061	.094	.42	.51	1.01	1.16	.49	.53	1.18	1.22	0	0	2.50	0	.41	.45	.63	1.12
New York	.025	.040	.061	.066	.39	.51	1.05	1.12	.52	.53	1.18	1.25	0	0	0	0	.36	.45	0	1.04
Pennsylvania	.025	.040	.061	.060	.37	.51	.97	1.04	.48	.53	1.17	1.20	0	0	0	0	.40	.45	.68	.88
Rhode Island	.025	.040	0	.082	.39	.51	0	1.16	.51	.53	0	1.22	0	0	0	0	.36	0	0	1.12
Vermont	.025	.040	0	.071	.39	.52	0	1.16	.51	.50	0	1.22	0	0	0	0	.36	0	0	1.12
Lake States:																				
Michigan	.023	.035	.060	.070	.36	.48	.99	1.05	.51	.50	1.17	1.18	0	0	0	0	.31	0	.61	.80
Minnesota	.023	.035	.070	.070	.37	.45	1.02	.98	.48	.50	1.23	1.25	0	0	0	0	.31	.43	.61	.81
Wisconsin	.023	.035	.060	.075	.35	.45	1.04	1.01	.48	.53	1.21	1.24	0	0	0	0	.32	.43	.61	.83
Corn Belt:																				
Illinois	.023	.030	.060	.070	.39	.45	1.04	1.06	.48	.52	1.25	1.26	0	0	0	5.0	.30	.38	.63	.81
Indiana	.023	.040	.060	.070	.38	.50	.99	1.01	.50	.50	1.18	1.23	0	1.50	2.50	0	.31	.41	.60	.78
Iowa	.023	.030	.045	.065	.36	.42	.95	.97	.47	.54	1.20	1.26	0	1.90	2.50	0	.29	.38	.59	.72
Missouri	.023	.030	.045	.050	.36	.44	.96	.99	.46	.46	1.20	1.18	0	1.20	2.50	2.25	.30	.42	.60	.73
Ohio	.023	.040	.060	.070	.36	.46	.97	1.01	.50	.50	1.17	1.23	0	0	0	0	.30	.40	.68	.81
Northern Plains:																				
Kansas	.020	.035	.055	.065	.37	.43	.98	.97	.47	.50	1.16	1.21	0	.80	2.50	4.20	.26	.32	.55	.69
Nebraska	.020	.045	.050	.065	.34	.45	.99	.96	.49	.51	1.19	1.27	0	1.20	2.50	3.00	.27	.35	.55	.55
North Dakota	.020	.037	.038	.065	.37	.45	1.03	1.00	.48	.55	1.20	1.28	0	0	2.50	0	.30	0	.59	.72
South Dakota	.020	.040	.045	.050	.37	.43	1.05	.98	.47	.49	1.13	1.26	0	0	2.50	3.50	.29	.41	.60	.72
Appalachia:																				
Kentucky	.023	.029	.045	.050	.38	.46	.96	.96	.48	.50	1.19	1.17	0	0	0	0	.33	.45	.66	.83
North Carolina	.023	.045	.050	.073	.37	.47	1.03	1.07	.49	.48	1.16	1.19	0	0	0	0	.31	0	.66	.77
Tennessee	.023	.025	.040	.050	.40	.50	1.02	.94	.48	.52	1.15	1.17	0	0	2.50	5.00	.34	.38	.67	.88
Virginia	.023	.045	.045	.075	.37	.48	1.03	1.06	.49	.50	1.15	1.21	0	0	0	0	.35	.42	.64	.83
West Virginia	.023	.055	0	.075	.37	.45	0	1.22	.49	.45	0	1.23	0	0	0	0	.35	0	0	.99

Continued—

See footnotes at end of table.

Appendix table 7—Prices used for energy cost calculations, by region and State—Continued

Region and State	Electricity per kWh				Diesel per gallon				Gasoline per gallon				Natural Gas per MCF ¹				Liquefied petroleum gas per gallon			
	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983	1974	1977	1980	1983
Dollars																				
Southeast:																				
Alabama	0.023	0.035	0.060	0.075	0.39	0.45	0.98	0.96	0.45	0.50	1.20	1.17	0	1.50	0	5.00	0.34	0.39	0.62	0.79
Florida	.023	.050	.060	.080	.37	.40	1.08	1.04	.47	.47	1.10	1.17	0	.90	2.50	0	.35	.37	.78	.88
Georgia	.023	.030	.050	.052	.38	.50	1.06	.96	.45	.55	1.15	1.16	0	0	0	0	.34	.42	.64	1.05
South Carolina	.023	.035	.040	.065	.42	.52	1.05	1.05	.47	.54	0	1.21	0	0	0	0	.35	.50	0	.88
Delta States:																				
Arkansas	.023	.040	.046	.070	.33	.46	.93	.96	.46	.57	1.16	1.17	0	1.80	2.50	4.20	.32	.45	.60	.79
Louisiana	.023	.028	.040	.080	.36	.45	.95	.91	.46	.52	1.15	1.17	0	.75	4.00	4.20	.30	.50	.67	.87
Mississippi	.023	.052	.065	.085	.38	.46	1.10	1.00	.48	.48	1.22	1.19	0	0	0	0	.33	.40	.61	.85
Southern Plains:																				
Oklahoma	.023	.030	.045	.070	.35	.45	1.02	1.01	.45	.55	1.17	1.16	0	1.20	2.50	3.50	.28	.44	.68	.76
Texas	.023	.030	.045	.065	.34	.45	1.00	.93	.43	.55	1.14	1.12	0	1.30	2.50	3.50	.29	.44	.60	.76
Mountain:																				
Arizona	.020	.021	.045	.045	.37	0	1.05	1.00	.48	0	1.17	1.19	0	1.50	2.50	5.30	.30	0	.73	.97
Colorado	.023	.035	.060	.075	.36	.45	1.01	.95	.46	.52	1.16	1.20	0	1.15	2.50	4.20	.29	.39	.59	.71
Idaho	.016	.016	.030	.030	.37	.45	.98	.97	.48	.50	1.18	1.22	0	0	2.00	4.50	.29	0	.63	.80
Montana	.016	.016	.040	.050	.35	.40	1.02	.98	.48	.45	1.22	1.25	0	0	0	0	.30	.35	.60	.73
Nevada	.015	.030	.050	.062	.40	.45	1.06	1.05	.50	0	0	1.24	0	0	0	0	.32	0	0	.92
New Mexico	.020	.035	.050	.076	.36	0	.99	1.00	.47	0	1.12	1.20	0	1.80	2.50	3.18	.28	.41	.69	.77
Utah	.015	.025	.035	.045	.40	.45	.97	1.02	.50	0	1.16	1.21	0	0	0	0	.32	.41	.70	.86
Wyoming	.023	.035	.030	.050	.36	.45	1.02	.99	.48	.50	1.19	1.18	0	0	3.00	4.00	.27	.43	.72	.77
Pacific:																				
California	.020	.042	.060	.062	.37	.50	.97	.97	.48	0	0	1.21	0	0	4.37	5.90	.30	0	0	.92
Oregon	.013	.014	.030	.042	.35	0	.97	.93	.46	0	0	1.18	0	0	0	0	.30	0	0	.77
Washington	.008	.011	.014	.026	.35	0	.97	.99	.49	0	0	1.27	0	0	0	0	.30	0	0	1.05
Alaska	.032	.040	.075	.075	.30	0	1.15	1.35	.60	.70	0	0	0	0	0	0	0	0	0	0
Hawaii	.030	.050	.075	.075	0	.60	0	0	.60	0	0	0	0	0	0	0	0	0	0	0

¹Natural gas was assumed to be \$0.75 per MCF for all States in 1974.

Appendix table 8—Estimated low-pressure center pivot irrigated area, United States, 1980¹

State	Center pivot irrigated area		State	Center pivot irrigated area	
	All	Low pressure		All	Low pressure
	1,000 acres			1,000 acres	
Alabama	66	7	New Mexico	246	81
Arkansas	70	35	North Dakota	137	54
Arizona	30	5	North Carolina	15	4
Colorado	633	317	Oklahoma	155	93
Delaware	21	5	Oregon	233	23
Florida	32	5	South Carolina	54	16
Georgia	618	370	South Dakota	239	12
Idaho	224	56	Tennessee	7	2
Illinois	103	5	Texas	543	80
Indiana	70	7	Virginia	16	3
Iowa	175	26	Washington	410	4
Kansas	988	293	Wisconsin	215	22
Louisiana	100	60	Wyoming	93	23
Maryland	31	18			
Michigan	152	30			
Minnesota	339	85	Total	9,127	2,153
Mississippi	100	90			
Missouri	131	26			
Montana	66	20			
Nebraska	2,815	282			

¹Estimated by irrigation specialists in their respective States.

Appendix table 9—Pump irrigated acres withheld from production for the Payment-in-Kind program, 1983

State	Acres withheld	State	Acres withheld
	1,000 acres		1,000 acres
Alabama	30	Nebraska	2,015
Arizona	328	New Mexico	190
Arkansas	120		
California	467	North Dakota	8
Colorado	240	Oklahoma	130
		Oregon	91
Idaho	60	South Carolina	15
Iowa	50	South Dakota	120
Kansas	717		
Louisiana	20	Texas	200
Michigan	40	Washington	266
Minnesota	130	Wisconsin	26
Missouri	45	Wyoming	13
Montana	125	Total	5,446

Appendix table 10—Selected estimates of irrigated land in the United States¹

State	U.S. Geological Survey, 1980	National Resource Inventory, 1982	Irrigation Journal, 1983	Census of Agriculture, 1982	State	U.S. Geological Survey, 1980	National Resource Inventory, 1982	Irrigation Journal, 1983	Census of Agriculture, 1982
1,000 acres					1,000 acres				
Alabama	75	89	161	67	Nevada	855	788	1,305	837
Arizona	1,319	1,198	1,150	1,105	New Hampshire	2	3	7	1
Arkansas	1,841	3,302	1,699	2,055	New Jersey	75	115	174	86
California	9,734	9,005	9,924	8,600	New Mexico	1,430	1,415	1,400	814
Colorado	2,680	3,171	2,790	3,222	New York	58	63	58	53
Connecticut	17	10	9	7	North Carolina	149	275	198	83
Delaware	11	50	50	48	North Dakota	175	205	211	163
Florida	2,041	1,868	2,282	1,611	Ohio	48	33	30	28
Georgia	997	1,057	1,183	612	Oklahoma	903	747	742	485
Idaho	4,047	3,560	4,057	3,480	Oregon	2,000	1,564	2,063	1,815
Illinois	150	168	151	162	Pennsylvania	63	10	21	18
Indiana	65	149	116	133	Rhode Island	4	4	3	2
Iowa	150	156	283	91	South Carolina	73	91	137	86
Kansas	3,406	3,498	3,489	2,700	South Dakota	387	55	457	379
Kentucky	14	16	29	23	Tennessee	21	18	33	19
Louisiana	743	1,284	663	697	Texas	7,700	9,761	7,800	5,485
Maine	11	11	5	6	Utah	1,187	1,312	1,203	1,096
Maryland	33	46	49	41	Vermont	2	1	2	1
Massachusetts	45	17	46	17	Virginia	41	97	85	44
Michigan	323	396	422	288	Washington	1,619	1,653	1,883	1,495
Minnesota	462	400	519	303	West Virginia	2	3	2	1
Mississippi	482	579	468	436	Wisconsin	236	327	253	261
Missouri	240	737	434	418	Wyoming	1,819	1,317	1,770	1,576
Montana	2,591	2,082	3,170	2,075					
Nebraska	7,099	7,097	8,088	6,080	U.S. total	57,425	59,803	61,074	49,105

¹These estimates of acres irrigated include all irrigated land. The indicated acres irrigated in the text of this report are only those acres irrigated with onfarm pumped water. Significant areas are irrigated without the use of onfarm pumps in some States.

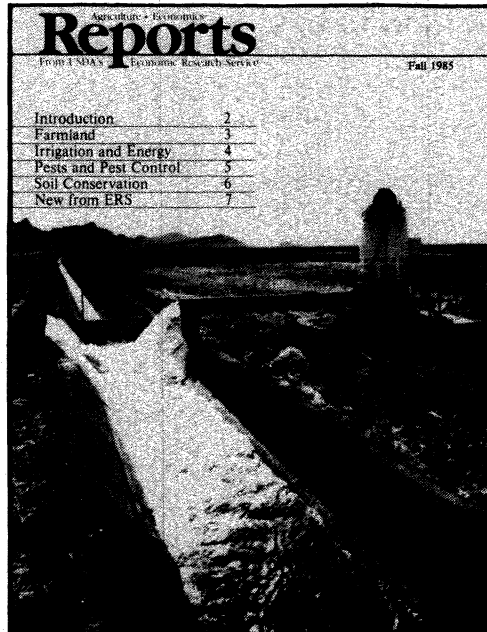
Part of the reason for the different estimates of acres irrigated is the different survey years. Most of the surveys are not annual so the same years cannot be compared. The definition of irrigated land also causes some differences. For example, the Census of Agriculture only includes land irrigated in the census year, and the National Resource Inventory land irrigated in 2 of the last 4 years. Other differences may be attributed to sample error.

Source: U.S. Geological Survey (23). National Resource Inventory (21). Irrigation Journal (10). Census of Agriculture (4).

Appendix III—State Irrigation Specialists

Alabama:	Larry Curtis, Agricultural Engineering, Auburn University, Auburn 36830	Indiana:	Rolland Wheaton, Extension Agricultural Engineering, Purdue University, West Lafayette 47901
Alaska:	Dale Schapester, USDA, Soil Conservation Service, Palmer 99645	Iowa:	Stewart W. Melvin, Agricultural Engineering, Iowa State University, Ames 50011
Arizona:	E. Neil Biggs, Agricultural Engineering, University of Arizona, Tuscon 85721	Kansas:	Dr. Richard Black, Agricultural Engineering, Kansas State University, Manhattan 66505
Arkansas:	Andy Hudson, USDA, Economic Research Service, Little Rock 72203	Kentucky:	Joseph R. Davis, USDA, Soil Conservation Service, Lexington 40507
California:	Gerald Knutson, Agricultural Engineering, Cooperative Extension, University of California, Davis 95616	Louisiana:	William A. Hadden, Agricultural Engineering, Louisiana State University, Baton Rouge 70803
Colorado:	Donald L. Miles, Cooperative Extension, Colorado State University, Rocky Ford 81067	Maine:	Vance E. Dearborn, Public Affairs, University of Maine, Orono 04473
Connecticut:	John Kolga, Agricultural Engineering, University of Connecticut, Storrs 06268	Maryland:	Lewis E. Carr, Agricultural Engineering, University of Maryland, Salisbury 21801
Delaware:	Thomas H. Williams, Agricultural Engineering, University of Delaware, Newark 19711	Massachusetts:	Cecil B. Currin, USDA, Soil Conservation Service, Amherst 01002
Florida:	Dalton S. Harrison, Agricultural Engineering, University of Florida, Gainesville 32611	Michigan:	Ron Van Til, Water Management Division, Department of Natural Resources, Box 30028, Lansing 48909
Georgia:	Kerry Harrison, Georgia Extension Service, Box 1209, Tipton 31793	Minnesota:	Jerry Wright, West Central Experiment Station, Morris 56267
Hawaii:	I-pai Wu, Agricultural Engineering, University of Hawaii, Honolulu 96822	Mississippi:	Lee Miller, Agricultural Engineering, Mississippi State University, State College 38677
Idaho:	Joel Hamilton, Agricultural Economics, University of Idaho, Boise 83843	Missouri:	Donald Pfof, Agricultural Engineering, University of Missouri, Columbia 65201
Illinois:	Emerson Nofziger, Agronomy, University of Illinois, Urbana 61801	Montana:	Robert W. Smith, Department of Natural Resources, 32 South Ewing, Helena 59601

Nebraska:	Paul E. Fischback, Agricultural Engineering, University of Nebraska, Lincoln 68583	Rhode Island:	Philip H. Wilson, University of Rhode Island, Kingston 02881
Nevada:	Dr. Tom Harris, Agricultural Economics, University of Nevada, Reno 89507	South Carolina:	C. V. Privette, Agricultural Engineering, Clemson University, Clemson 29631
New Hampshire:	B. P. Batchelder, USDA, Soil Conservation Service, Durham 03824	South Dakota:	Charles Ullery, Water Resources Institute, South Dakota State University, Brookings 57006
New Jersey:	Harold Carpenter, Extension Service, Rutgers Research and Development Center, Bridgeton 08302	Tennessee:	H. O. Vaigneur, Agricultural Extension, University of Tennessee, Jackson 38301
New Mexico:	Robert Lansford, Agricultural Economics, New Mexico State University, Las Cruces 88002	Texas:	Comer Tuck, Texas Department of Water Resources, Austin 78711
New York:	Joseph K. Campbell, Agricultural Engineering, Cornell University, Ithaca 14850	Utah:	Richard E. Girfin, Extension Water Resource Specialist, Utah State University, Logan 84321
North Carolina:	Ronald Sneed, Agricultural Engineering, North Carolina State University, Raleigh 27607	Vermont:	Grant Wells, University of Vermont, Burlington 05404
North Dakota:	Darnell Lundstrom, Extension Agricultural Engineering, North Dakota State University, Fargo 58102	Virginia:	Burton B. Ross, Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg 24061
Ohio:	Melville L. Palmer, Agricultural Engineering, Ohio State University, Columbus 43210	Washington:	Thomas Ley, Irrigated Agriculture, Research and Extension Center, Prosser 00350-0030
Oklahoma:	Delbert Schwab, Agricultural Engineering, Oklahoma State University, Stillwater 74078	West Virginia:	Arthur W. Selders, Agricultural Engineering, West Virginia University, Morgantown 26506
Oregon:	Hugh J. Hansen, Agricultural Engineering, Oregon State University, Corvallis 97331	Wisconsin:	L. E. Massie, Extension Agricultural Engineering, University of Wisconsin, Madison 53706
Pennsylvania:	N. H. Wooding, Extension Agricultural Engineering, Pennsylvania State University, University Park 16802	Wyoming:	Donald J. Brosz, Extension Irrigation Engineer, University of Wyoming, Laramie 82071



Free Catalogue of USDA Reports

Stay current on developments in **LAND VALUES, RESOURCE USE and CONSERVATION, PEST MANAGEMENT, and NATURAL RESOURCE POLICY** with the latest issue of *Reports*, a quarterly catalogue of new publications from USDA's Economic Research Service. To receive your copy of this free catalogue, send your name and address to: Reports, USDA-EMS, 1301 New York Avenue, Rm. 237, Washington, D.C. 20005-4788.

